Innovation, Technology, and Knowledge Management

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Knowledge Perspectives of New Product Development

A Comparative Approach

Springer

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Series Foreword

The Springer book series *Innovation, Technology, and Knowledge Management* was launched in March 2008 as a forum and intellectual, scholarly "podium" for global/local, transdisciplinary, transsectoral, public–private, and leading/"bleeding"-edge ideas, theories, and perspectives on these topics.

The book series is accompanied by the Springer *Journal of the Knowledge Economy*, which was launched in 2009 with the same editorial leadership.

The series showcases provocative views that diverge from the current "conventional wisdom," that are properly grounded in theory and practice, and that consider the concepts of *robust competitiveness*,[1] *sustainable entrepreneurship*,[2] and *democratic capitalism*,[3] central to its philosophy and objectives. More specifically, the aim of this series is to highlight emerging research and practice at the dynamic intersection of these fields, where individuals, organizations, industries, regions, and nations are harnessing creativity and invention to achieve and sustain growth.

Books that are part of the series explore the impact of innovation at the "macro" (economies, markets), "meso" (industries, firms), and "micro" levels (teams,

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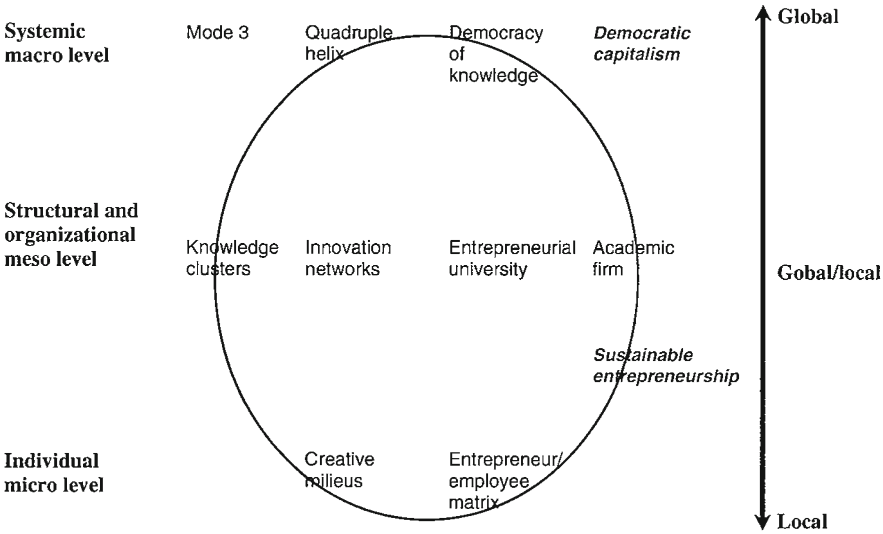
[1] We define *sustainable entrepreneurship* as the creation of viable, profitable, and scalable firms. Such firms engender the formation of self-replicating and mutually enhancing innovation networks and knowledge clusters (innovation ecosystems), leading toward robust competitiveness (E.G. Carayannis, *International Journal of Innovation and Regional Development* 1(3), 235–254, 2009).

[2] We understand *robust competitiveness* to be a state of economic being and becoming that avails systematic and defensible "unfair advantages" to the entities that are part of the economy. Such competitiveness is built on mutually complementary and reinforcing low-, medium-, and high-technology and public and private sector entities (government agencies, private firms, universities, and nongovernmental organizations) (E.G. Carayannis, *International Journal of Innovation and Regional Development* 1(3), 235–254, 2009).

[3] The concepts of *robust competitiveness* and *sustainable entrepreneurship* are pillars of a regime that we call "*democratic capitalism*" (as opposed to "popular or casino capitalism"), in which real opportunities for education and economic prosperity are available to all, especially – but not only – younger people. These are the direct derivative of a collection of top-down policies as well as bottom-up initiatives (including strong research and development policies and funding, but going beyond these to include the development of innovation networks and knowledge clusters across regions and sectors) (E.G. Carayannis and A. Kaloudis, *Japan Economic Currents*, p. 6–10 January 2009).

individuals), drawing from such related disciplines as finance, organizational psychology, research and development, science policy, information systems, and strategy, with the underlying theme that for innovation to be useful it must involve the sharing and application of knowledge.

Some of the key anchoring concepts of the series are outlined in the figure below and the definitions that follow (all definitions are from E.G. Carayannis and D.F.J. Campbell, *International Journal of Technology Management*, 46, 3–4, 2009).



Conceptual profile of the series *Innovation, Technology, and Knowledge Management*

- The “Mode 3” Systems Approach for Knowledge Creation, Diffusion, and Use: “Mode 3” is a multilateral, multinodal, multimodal, and multilevel systems approach to the conceptualization, design, and management of real and virtual, “knowledge-stock” and “knowledge-flow,” modalities that catalyze, accelerate, and support the creation, diffusion, sharing, absorption, and use of cospecialized knowledge assets. “Mode 3” is based on a system-theoretic perspective of socio-economic, political, technological, and cultural trends and conditions that shape the coevolution of knowledge with the “knowledge-based and knowledge-driven, global/local economy and society.”
- Quadruple Helix: Quadruple helix, in this context, means to add to the triple helix of government, university, and industry a “fourth helix” that we identify as the “media-based and culture-based public.” This fourth helix associates with “media,” “creative industries,” “culture,” “values,” “life styles,” “art,” and perhaps also the notion of the “creative class.”

- Innovation Networks: Innovation networks are real and virtual infrastructures and infratechnologies that serve to nurture creativity, trigger invention, and catalyze innovation in a public and/or private domain context (for instance, government–university–industry public–private research and technology development coopetitive partnerships).
- Knowledge Clusters: Knowledge clusters are agglomerations of cospecialized, mutually complementary, and reinforcing knowledge assets in the form of "knowledge stocks" and "knowledge flows" that exhibit self-organizing, learning-driven, dynamically adaptive competences and trends in the context of an open systems perspective.
- Twenty-First Century Innovation Ecosystem: A twenty-first century innovation ecosystem is a multilevel, multimodal, multinodal, and multiagent system of systems. The constituent systems consist of innovation metanetworks (networks of innovation networks and knowledge clusters) and knowledge metaclusters (clusters of innovation networks and knowledge clusters) as building blocks and organized in a self-referential or chaotic fractal knowledge and innovation architecture (Carayannis 2001), which in turn constitute agglomerations of human, social, intellectual, and financial capital stocks and flows as well as cultural and technological artifacts and modalities, continually coevolving, cospecializing, and cooperating. These innovation networks and knowledge clusters also form, reform, and dissolve within diverse institutional, political, technological, and socioeconomic domains, including government, university, industry, and nongovernmental organizations and involving information and communication technologies, biotechnologies, advanced materials, nanotechnologies, and next-Generation energy technologies.

Who is this book series published for? The book series addresses a diversity of audiences in different settings:

1. *Academic communities*: Academic communities worldwide represent a core group of readers. This follows from the theoretical/conceptual interest of the book series to influence academic discourses in the fields of knowledge, also carried by the claim of a certain saturation of academia with the current concepts and the postulate of a window of opportunity for new or at least additional concepts. Thus, it represents a key challenge for the series to exercise a certain impact on discourses in academia. In principle, all academic communities that are interested in knowledge (knowledge and innovation) could be tackled by the book series. The interdisciplinary (transdisciplinary) nature of the book series underscores that the scope of the book series is not limited a priori to a specific basket of disciplines. From a radical viewpoint, one could create the hypothesis that there is no discipline where knowledge is of no importance.
2. *Decision makers – private/academic entrepreneurs and public* (*governmental, subgovernmental*) *actors*: Two different groups of decision makers are being addressed simultaneously: (1) private entrepreneurs (firms, commercial firms, academic firms) and academic entrepreneurs (universities), interested in optimizing knowledge management and in developing heterogeneously composed

knowledge-based research networks; and (2) public (governmental, subgovernmental) actors that are interested in optimizing and further developing their policies and policy strategies that target knowledge and innovation. One purpose of public *knowledge and innovation policy* is to enhance the performance and competitiveness of advanced economies.

3. *Decision makers in general*: Decision makers are systematically being supplied with crucial information, for how to optimize knowledge-referring and knowledge-enhancing decision-making. The nature of this "crucial information" is conceptual as well as empirical (case-study-based). Empirical information highlights practical examples and points toward practical solutions (perhaps remedies); conceptual information offers the advantage of further-driving and further-carrying tools of understanding. Different groups of addressed decision makers could be decision makers in private firms and multinational corporations, responsible for the knowledge portfolio of companies; knowledge and knowledge management consultants; globalization experts, focusing on the internationalization of research and development, science and technology, and innovation; experts in university/business research networks; and political scientists, economists, and business professionals.
4. *Interested global readership*: Finally, the Springer book series addresses a whole global readership, composed of members who are generally interested in knowledge and innovation. The global readership could partially coincide with the communities as described above ("academic communities," "decision makers"), but could also refer to other constituencies and groups.

Washington, DC Elias G. Carayannis

Preface

New Product Development (NPD) is about the ideation, formulation, and implementation of new and superior solutions in the market on a cost/benefit basis. It relies upon and leverages people, culture, and technology, and has both a universality as well as a uniqueness in its texture and impact (consider, for instance, e-books, smart phones and electric vehicles as examples), and, for that matter, it is often driven by twenty-first-century innovation workshops, such the IDEO labs in California or other such creativity hubs as stand-alone entities and/or units within corporate structures.

The applications and implications of NPD tools, methodologies, and techniques in a world where change is not just constant, but accelerating (i.e., speed and acceleration of innovation), can be instrumental and truly decisive and even disruptive of markets and technological trajectories with substantial value creation potential. NPD can help trigger technology lifecycles that may result in significant new dominant designs and standards that may open new socioeconomic vistas, making sustainable and profitable solutions that were previously considered technically infeasible and/or economically nonviable.

In particular, in the context of the race for reducing the global economy's carbon footprint to ensure that our planet (and everyone on it) has a future, NPD may be a truly strategic "trump card," as it may change the socio-technical and sociopolitical calculus regarding approaches that may be critically needed. In this sense, NPD may act as an enabler of positive disruption and bottom-up, grass-roots-driven socio-technical change that may help overcome and leapfrog incumbent technological regimes and economic standards and practices that act against the common good.

The old truisms that being close to a market is critical for understanding a market, and that understanding a market is critical for innovation of that market, are still true. However, as marketplaces become increasingly global due to digitization (e.g., the market for iTunes), "closeness" to a market acquires new meanings that include understanding many key markets as well as the ability to abstract the common elements of each. In this sense, NPD leverages globalization and glocalization trends to trigger, as well as catalyze and accelerate, innovation, diffusion and adoption of innovations at local, as well as regional and transnational, levels.

This book provides an array of knowledge perspectives in NPD across multiple levels of analysis, as well as geographies spanning the globe, including several EU countries, both large (i.e., Germany, France) and small (i.e., Estonia, Greece), the United States, Japan, China, and India. It presents 14 conceptual and empirical studies that contribute to the theory and practice of NPD in a comparative approach and across a broad range of knowledge-intensive industries and sectors, including ICT services, semiconductors, software development, biotechnology, higher education, and even safety for juvenile products.

More specifically, several chapters present empirical findings not only from developing small national economies, such as Estonia (Chap. 1), but also large and developed economies, such as Japan (Chap. 10), where the transformation of the institutional framework for innovation and NPD has fuelled new innovative strategies for growth. They also include illustrative cases from the rapidly growing BRIC countries (Chap. 11) in assessing the role of higher education in preparing India for new product and service technology, and China (Chap. 13) in terms of cooperative innovation for the biotech industry.

Lessons from recent EU-supported projects addressing questions at both the national and supranational level of analysis are discussed in Chap. 2, focussing on factors affecting the performance of NPD teams of large multinational enterprises (MNEs) across Europe and beyond. Cross-functional NPD teams at the mesolevel, bringing together people and business units collaborating across functional/disciplinary, institutional, and geographical boundaries, are explored in detailed case studies at Chaps. 3 and 4.

A part of the book also addresses head on the creative tension between mainly large MNEs, their NPD teams, and the regional innovation system, or industrial cluster, where these teams are embedded and from where they draw knowledge. Chapter 5 deals with the notion of regional embeddedness of MNEs and analyzes how NPD (and, more broadly, innovation) is shaped by the regional environment where MNEs are located throughout Europe. The link between environmental and collective competences is further elaborated and a new model of interorganizational competences for collaborative NPD it is put forward in Chap. 6.

Additionally, Chap. 7 looks into the leader–member relationship at innovation development with member perceptions, positions, and expectations in focus. On the other hand, Chap. 8 reflects on science–industry cooperation and examines bilateral R&D cooperations attempting to balance a system-based institutional approach and an actor-based approach that takes into account individual characteristics for explaining how cooperation is established in the very early stages before there is a formal agreement for NPD.

Moreover, Chap. 9 presents an interesting case for radical innovation and NPD from Germany, where in the traditional market of road tolling equipment, a newcomer company anticipated and combined previously unrelated trends in the technological, institutional, and market domains to introduce the core of the new system and yield strategic advantage.

Shifting the emphasis from the private to the public sector and to government initiative, Chap. 12 reflects on the role that the Bayh-Dole Act played in the United

States and beyond for technology transfer from American research-led universities to firms, also putting forward alternative models for technology transfer, such as inventor, rather than university, ownership of the invention.

Last but not least, Chap. 14 presents an exploratory study of NPD practices in leading firms in the juvenile products industry in China and worldwide, shedding light on the relationships between NPD and product safety.

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Chapter 1
How Path Dependency Affects Innovative Behavior of Firms

Elias G. Carayannis, Kadri Ukrainski, Jaan Masso, and Urmas Varblane

1.1 Introduction

Within the last decade, the need to increase innovativeness and knowledge based strategies of development was actively discussed. Particularly strong recommendations are given to the new EU members to restructure again their economies – firms and industries should increase their value added content and knowledge intensity of production. However, in this context, it is important to figure out, which speed of change is feasible in those firms and industries. How does the previous development path of the individual firms and industries hinder or support the possible alternatives in trying to change/upgrade their role in global value chains? Therefore, the current article is going to tackle the issue of path dependency of industries in choosing their innovation behavior (from the innovation inputs, processes and outcome point of view).

The aim of the paper is to analyse the extent to which path-dependency is shaping innovative activities and their outcomes by considering the composite indicators of input, process, output, and environment. The broader idea of the paper is to identify the set of innovation indicators on which the firms/sectors are similar in their behavior for responding to general changes in competitiveness of a branch. Path dependency is a concept that has been criticized by being a fashionable label for the intuition that "history matters" without a clear and convincing account of decision-making over time, explaining only stability and not change; and its normative implications are confused and mostly left unexplored (Kay 2005). In this paper we try to

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capture some dynamic aspects of path dependency by assessing it through the level and dynamics of value added created in production in different industries.

Certainly the path dependency could be revealed better in the process of comparing firms and industries in countries with different economic, political, historical development. However, path dependency could be, to some degree, revealed also comparing different industries in a single country. Each industry has its own development trajectory, which could be measured by many technological, financial, social indicators described in the literature about the sectoral systems of innovation. The other group of theoretical concepts leading to the formulation of a theoretical framework in this paper are rooted in the resource-based theory of the firm, which sees firms as knowledge reservoirs, and in evolutionary economics, which sees innovation as an outcome of (path-dependent) knowledge production and use.

The paper proceeds as following: at first the concepts of dynamic capabilities and path dependency are opened and their relationship with the innovation behavior of firms and industries are discussed. Thereafter, the sectoral aspects of path dependency are clarified and the framework for empirical estimation is constructed. Subsequently, the data and methods of estimation are described and the results are presented together with discussion and possibilities for further research.

1.2 Innovative Behavior of Firms and Path Dependency

The concept of path dependency is used to describe contingent, irreversible, dynamic, evolutionary processes in the economy expressing the view that technological change in a society depends quantitatively and/or qualitatively on its own past (Mokyr 1990: 163). The evolutionary theory from Nelson and Winter (1982) emerged out of an interest in analysing the relationship between technical change and economic growth in which the interfirm differences matter. Since individuals are bounded in their decisions, firms use decision rules and procedures to guide their actions, and these routines explain the behavior of firms (Nelson and Winter 1982: 128). In their approach, the firm becomes a repository of knowledge, which is contingent on the firm's past (on routines where knowledge is stored) and what makes one firm different from another (Fransman 1998: 171). The firm searches through a variety of alternatives for problem-solving activities and selects them according to its routines.

The similarity can be seen with the preceding theory from Penrose (1959), who views the firm as a collection of productive resources rendering services, which are specific to each firm depending on the accumulated knowledge within the firm (Penrose 1959: 25). These services are used for productive activities following the changing productive opportunities the firm sees, given its resources. As Teece et al. (1997: 13) concluded: *The resource-based approach sees firms with superior capabilities and/or organizational structures being profitable not because they raise prices above long-run costs, but because they have markedly lower costs, or offer markedly higher quality of product performance*. This (emerging) capabilities approach tries to overcome the inability of traditional static models to explain the dynamic behavior of firms (Von Tunzelmann and Wang 2007: 192–193). This approach combines the theory from Penrose with a similar model for consumption by Sen (1985) incorporating the characteristics of goods, the individual capabilities of the consumer to use or consume them and the utility obtained from both, and how the characteristics of goods respond to the needs of the consumer (functionings) and from the set of capabilities to use or obtain utility from the goods (capabilities). Of course, the capabilities can be improved by obtaining skills to use new products or technologies. Similarly, the firms have product possibilities, production capabilities, and profitability (or appropriability) with regard to production in general, but the model can be narrowed down to describe the capabilities in technology, whereby the process of creation of technology can be separated from the production process (Von Tunzelmann and Wang 2007: 92–211).

Chandler (1990) discussed about accumulated dynamic capabilities during the existence of the firm and their relevance in exploiting technological opportunities or competitive advantages. The accumulation of the capabilities lies at the core of the concept of path-dependency. The capabilities of firms are aligned with the circumstances where specific firm is operating in real time (dynamic competition from Schumpeter) and with the respective learning mechanisms termed dynamic interactive capabilities (Von Tunzelmann and Wang 2007: 202). From the point of view this paper, the approach of dynamic capabilities stresses the idea that such capabilities arise due to internal processes of firms, which facilitate learning, firm's access to specific competences and its path, trajectory of development of firm as change is always path dependent. The dynamic capabilities approach refers to the exploiting existing internal and external firm-specific competences to address changing environment (Teece et al. 1997). Therefore, dynamic capabilities can be defined as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions (Teece et al. 1997: 516).

In order to describe different abilities of firms and other organizations to improve their competitive advantage the concept of upgrading is used among the researchers of strategic management. They identify four trajectories which firms can adopt in pursuing the objective of upgrading (Kaplinsky and Morris 2001: 38):

(a) Process upgrading: increasing the efficiency of internal processes.
(b) Product upgrading: introducing new products or improving old products faster than rivals.
(c) Functional upgrading: increasing value added by changing the mix of activities conducted within the firm.
(d) Chain upgrading: moving to a new value chain (e.g., Taiwanese firms moving from the manufacture of transistor radios to calculators, to TVs, to computer monitors, to laptops, and now to WAP phones).

The above-described areas of upgrading require certain innovative behavior, for instance process upgrading requires process innovations, product upgrading needs product innovations, and functional upgrading requires a more complicated mix of organizational, marketing, and other innovations. Therefore, the dynamic capabilities of firms will be manifested in the design of different upgrading strategies involving various types of innovative behavior.

Thus far, we have argued that the competences and capabilities (and hence competitive advantage) of a firm rest fundamentally on processes, shaped by positions and paths (Teece et al. 1997: 525). These development paths can be characterized by the factors inducing the technological change, which, for instance, according to Dosi (1988), are as follows: technological bottlenecks in interrelated activities, scarcities of critical inputs or conversely, abundance of particular inputs (like energy, raw materials, etc.), composition, changes and rates of growth of demands, levels and changes in relative prices (first of all labor to machinery), and patterns of industrial conflict. In addition, existing networks can be considered relevant. Not only is the existence of networks relevant for learning as it sometimes seems from the discussions in the literature. Networking is the means for realizing a common path of development through learning. Coombs and Hull (1998) proposed that the path dependency is potentially located in three domains within the firm: technology as a hardware, knowledge base of the firm and as the collection of routines. They also indicated on the interrelatedness of those three domains. The knowledge base structures routines, which deploy knowledge to create technology.

The evolutionary approach makes the nature of knowledge and firms' investment in it a central factor in explaining the size, structure, and dynamics of industries (Pavitt 2002). Empirical studies show that within industries different rates of investment in knowledge determine the likelihood of firms' survival and growth (Klepper and Simons 1997). The development of technology in different fields seems to have specific path dependency as well, and hence one speaks about technological trajectories and paradigms (Dosi 1988: 1128–1130). The empirical evidence shows that sectoral patterns of innovative activities differ, but for each sectoral system similarities across countries do exist (Malerba and Orsenigo 1996). These similarities in sectoral systems stem from the features of technological regimes, knowledge base and learning processes that are relatively invariant across countries (Breschi et al. 2000). Similarities have been found in appropriability conditions and cumulativeness conditions of knowledge across countries; however the creation and exploitation of the technological opportunities is less similar across countries, because it is related to the level and specifics of the university research, of science-industry bridging mechanisms, inter-firm networks, and the types and level of innovation efforts of firms (Nelson 1993).

The path dependency in sectoral level is expressed by the technological trajectories and knowledge bases and learning which are cumulative and build upon the earlier technology, knowledge, or learning. However, the concept of path dependencies is also given forward meaning through the consideration of an industry's technological opportunities. It is widely acknowledged that how far and how fast a particular area of industrial activity can proceed is, in part due to the technological opportunities that lie before it. Such opportunities are usually a lagged function of foment and diversity in basic science, and the rapidity with which new scientific breakthroughs are being made. However, technological opportunities may not be completely exogenous to industry, not only because some firms have the capacity to engage in or at least support basic research, but also because technological opportunities are often fed by innovative activity itself. Moreover, the recognition of such opportunities is affected by the organizational structures that link the institutions engaging in basic research (primarily the university) to the business enterprise (Teece et al. 1997: 524–525).

In addition to the path dependence in sectors, there is a specific path dependence for firms and industries in transition countries. It is important to understand the role of firms in catching up processes. Previous research has stressed that firms have only imperfect knowledge about the relevant options before them and that they tend to be myopic, searching the neighbourhood of their existing competence for relevant information, suggestions and solutions (Nelson and Winter 1982; Dosi 1988; and Fagreberg and Godinho 2003). The firms from new EU member states may be much more constrained by its environment than firms in highly developed countries. They may have a wish and even the capability to introduce a new product or process, but the possibility to do so may depend on capabilities of other firms or skills that do not exist or require substantial investments (see Fagreberg and Godinho 2003). It means that they are not free in choosing development path and their catching up may be hindered.

This discussion brings in the concepts of "latecomer disadvantages" and "latecomer advantages" (Gerschenkron 1962). Hobday (1995) defined latecomer firms in terms of their deficiencies of technology and market access and later Mathews (2002) captured it into the notion of "resource deficiency." The latecomer country and its firms face initial serious disadvantages mentioned above, but, in addition, they also have some potential advantages if they know how to use them. Southeast Asian countries had the advantage of starting with a "clean slate" – without commitments to any particular technology or approach (Mathews 2007). As Mathew mentioned, the first "competitive advantage" of latecomer firms lies in recognizing its deficiencies. It helps to formulate a strategy commensurate with its deficiencies and limitations. (Mathews 2002). It is driven by a strategy that searches for ways of capturing resources (technology, knowledge, and market access), which can then be internalized and turned into dynamic capabilities needed to compete in demanding, technology-intensive markets. This approach consists of generation linkage with global value chains, leverage of resources through those linkages and learning as the outcome of repeated applications of linkage and leverage by the latecomer firms, resulting in the acquisition of dynamic capabilities (Mathews 2002, 2007).

1.3 The Framework for Analysing Path Dependency and Innovative Behavior

Path dependency is a concept that has been criticized by being a fashionable label for the intuition that "history matters" without a clear and convincing account of decision-making over time, explaining only stability and not change; and its normative implications are confused and mostly left unexplored (Kay 2005).

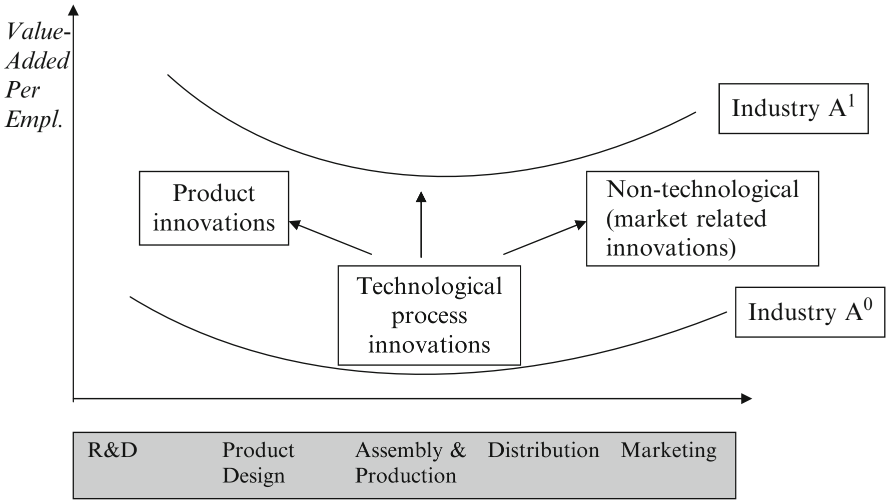

Fig. 1.1 The innovative behavior of firm and resulting level of value added (elaborated from Dhanani and Scholtès 2002: 3)

Therefore, path dependency should be somehow operationalized – regarding which indicators the path dependency is embedded. In the current paper the initial level and dynamics of the value added that is produced is used as the proxy reflecting the position and previous development of firms and industries. It reflects how successful the firm or the industry has been so far in competing on the domestic and international markets. Value added per employee is considered typically as an indicator of productivity or proxy for competitiveness, but could be also taken as certain expression about the path-dependency of a firm or of an industry. Value added is a synthetic indicator reflecting the scarcities or abundance of labor inputs through the labor costs, the conditions of market demand, the relative position of the firm on the market or in the value chain (through the price margin that the firm can reap from the markets), growth of demands, levels and changes in relative prices (labor to other costs). The average level of value-added per employee in an industry and respective dynamics can reflect the development path of this industry in quite many aspects. The level of value added is also reflecting the limits of the firm in choices on innovative behavior.

In the following discussion, the impact of value added as an indicator of path dependency on inputs, processes, and outcomes of innovative activities is discussed. Different innovative activities and level of value added are related as shown in Fig. 1.1, which describes the value chain of certain industry. On the horizontal axes, various activities in the value chain as well as accompanied innovation processes are presented. On the vertical axes the relative level of the value added per employee is given. According to the results of previous research (Dhanani and Scholtès 2002) for any particular manufactured product, the highest value added could be achieved either by moving towards R&D and design or toward marketing/branding activities.

The value added can be increased in production activities as well by improving the technological processes of manufacturing and shifting to the higher production curve, which could be presented in Fig. 1.1 as upward shift.

Figure 1.1 can be extended to outline broad differences by industry and country groups, whether the major innovative behavior is towards technological or nontechnological process innovation or product innovation. However, within a country different sectors may be positioned differently (as in Fig. 1.1, some sectors might be advanced in their levels of value added, some are further behind). Within a country then, the different level of value added across industries reflects from one side varying cost structure (depending not only on the technologies but also on costs of inputs, such as labor and capital) but from another also varying appropriability conditions (dependingon the power to reap higher margins from sales). The dynamics in value added can be reflecting, therefore, changes in both sides. The worsening conditions of increasing costs or decreasing price levels for final products lead to decrease in value added; however the contrary conditions, but also more advanced and efficient production technology (or other process innovation such as marketing, organizational, or logistics) aimed at lowering costs leads to increase in value added. Therefore, the average level of value added can represent a measure of broader conditions of competitiveness or environment for a single firm from which the firm should develop its innovation behavior.

The idea might be that in every box there might be certain kinds of innovative activities dominating, and both the motives for innovations as well as abilities to innovate differ. International (particularly East Asian) experience from the last decades suggests that most widely used development path proceeds from the process to product upgrading and then to functional, and finally to chain upgrading. It is a well-known path from OEA production (original equipment assembling) to OEM (original equipment manufacturing manufacturer), further to ODM (own design manufacturer), and finally to OBM (own brand manufacturing) (Kaplinsky and Morris 2001; Mathews 2007). The different trajectory of upgrading would explain also the different emphasis on innovative behavior. It starts with strong emphasis on the process innovation including technological and organizational aspects of the process management. Thereafter, the product innovation is invested in and then efforts to marketing innovations (up to branding) are pursued.

1.4 Data and Method

Traditionally, the innovativeness of firms is reflected by a single/few innovation indicator(s); however, for a more comprehensive understanding of firms innovative behavior, a complex set of indicators is needed reflecting the process of innovation in its different aspects. For the measurement of the innovation processes in a more comprehensive way, the set of indicators can be considered as depicted in Fig. 1.2. The set of indicators is similar to the 3P model proposed by Carayannis and Provance (2008), including the firm's propensity to innovate (input and process indicators)

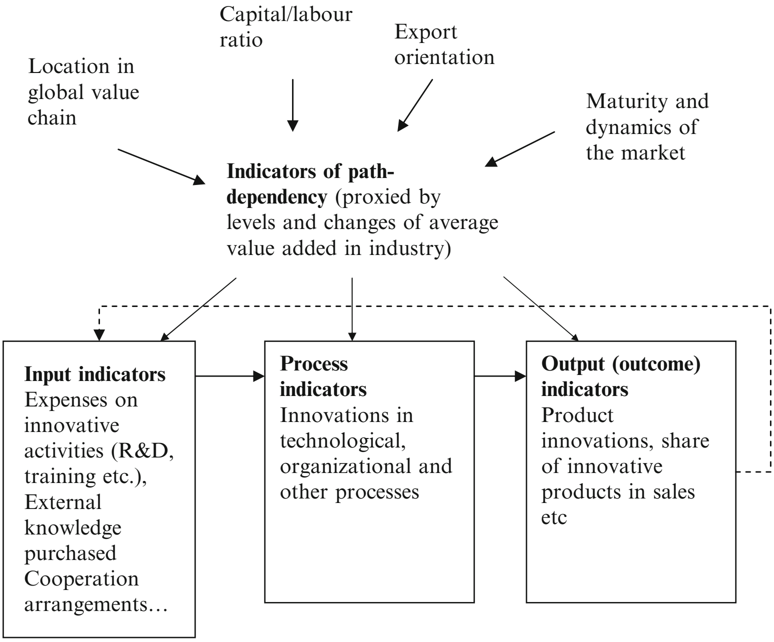

Fig. 1.2 Indicators describing firm's innovative behavior

and results in performance (output and outcome indicators) across different environmental conditions (mainly conditions of different development paths proxied by the indicator of value added and its changes) in different time periods. The latter can reflect, to some extent, the posture of a firm (firm's position within a broader innovative system or environment regional, technological, etc.); additional posture aspects can be included by analysing the firm-specific barriers to innovation. It has to be noted, that value added can be considered as the outcome of firm's activities in a given period. At the same time, especially considering the longer period average value added of an industry, it reflects the changes in environment the firms are operating in. It could be influenced by the several indicators of path dependency – position of firms in global value chain, general capital labor ratio (given by existing technologies), export orientation of a sector, maturity, and growth of the market, etc. (see also Fig. 1.2).

Value added considers the additional value created at a particular stage of production or through image and marketing. Especially in macroeconomics (the System of National Accounts approach), it refers to the contribution of the factors of production for raising the value of a product and corresponds to the incomes received by the owners of these factors and, therefore has been used mostly held the best way for measuring productivity (Meade 2007).

However, as Von Tunzelmann and Wang (2007) highlighted, this type of traditional productivity measure is not a good indicator for measuring technological productivity, instead the success should be measured by the ability to produce still more technology.

For the current analysis we are using the Estonian Community Innovation Survey (CIS) IV data that cover the years 2002–2004. The survey includes questions about innovative activities, expenditures on various innovative activities, the outcomes of innovative activities, innovation cooperation, sources of information for innovation, obstacles to innovative activities, and nontechnological innovations (organizational and marketing innovations). The survey comprised 1,747 firms. The response rates in the survey were rather high, 78% in CIS IV, while the EU average has remained 55% (Terk et al. 2007). The CIS IV data are combined with the Estonian Business Register database on the population of all firms, including the data on the firm's financial reports (balance sheets, profit and loss statements).

The measurement of innovation performance, in terms of eitherinnovation inputs or innovation outputs, is not a straightforward task for the researchers. Carayannis and Provance (2008) summarized that while the measurement of innovation at the firm level has been paid less attention than at the project level, due to the disparities at the firm-level studies any generally accepted firm-level innovation performance indicator has not been evolved. While several studies have determined the innovative performance by using just a single innovation indicator (e.g., R&D expenditures, patents, patent citations, and new products – see, e.g., Hagedoorn and Cloodt 2003 for review), there are various problems associated with the use of single indicators, e.g., measurement errors in input indicators[1]; output variables such as patents need not represent all kinds of innovations, etc. Kleinknecht et al. (2000) argued that the choice between different indicators is not trivial and it depends on what one wants to investigate; they argued that R&D and patenting have more shortcomings than direct measures of innovation output. Thus, the few studies using composite or multiple innovation indicators have argued in favor of using these for the innovation measurement. Hollenstein (1996) derived a composite indicator for Swiss manufacturing and argued that the composite indicator was superior to any individual single indicators as shown by canonical correlations. Hagedoorn and Cloodt (2003) found from the study of the international sample of high-tech companies that the composite indicator caught the latent variable "innovative performance."

Hereby, we follow, to some extent, the approach of Carayannis and Provance (2008) to the construction of composite innovation indicators. However, since we use a quite different dataset than they did, we need to reconsider the choice of particular innovation indicators. In total, we have considered 30 measures (individual indicators) for the creation of the composite innovation indicator. The list of indicators together with their definitions and summary statistics can be found in Appendix 1.

[1] For example, in case of Estonian CIS data it has been revealed that the same enterprises have reported rather different R&D expenditures in R&D survey and innovation survey. Both in case of CIS3 and CIS4, internal R&D expenditures were higher according to innovation survey than the R&D survey. The difference between the two surveys was smaller in the case of CIS4 which may indicate the decreasing measurement errors (Heinlo 2006).

Basically, we perform the factor analysis of innovation input indicators, process innovation indicators, and innovation output and outcome indicators.

Innovation input indicators should measure the resources that firms have devoted to the innovative activities. The list of innovation input indicators includes the different sources of knowledge for innovation (suppliers, customers, competitors, consultants, universities, etc.)and different barriers or obstacles to innovation (lack of finance, lack of qualified personnel, lack of information on technology, etc.). In addition, input indicators include four different kinds of expenditures on innovation – in-house R&D and external R&D costs, purchasing costs of machinery and equipment, and the purchasing costs of other external knowledge. The variable for total investments in fixed assets during (1995–2004) proxies for the overall access to finances and ability to invest. The average log number of employees during 1995–2004 is a measure of the firm size. Previous research has shown that larger firms are more likely to engage in innovative activities than small firms. The dummy for foreign-owned firms is included because these firms may have quite different knowledge sources for innovative activities (the knowledge from the mother company in abroad); however, their motivation for doing R&D could differ as well if the R&D activities are concentrated on the parent company. Dummy for public sector equals 1 if the firm has received support from any public sources (central government, local government, or from abroad, like from EU Framework Programmes).[2]

Process indicators are to reflect the organizational and innovation process management systems (Carayannis and Provance 2008). The list of our process-oriented measures includes the technological process innovation (new or significantly improved production method), delivery process innovation, innovation in supporting activities, knowledge management (new or improved knowledge management systems), organizational innovation, relations to other firms, and design or marketing. All these are dummy variables taking the value 1 if the firms have reported having undertaken such a form of innovation.

Output and outcome indicators represent the success or results of innovative activities. In the literature sometimes the output and outcome indicators are distinguished: while output indicators represent the shorter-term success of the innovative activity (e.g., patents, new products, and share of sales from new products), outcome indicators show the long-term success of innovative activities such as profit margin and, market share (Carayannis and Provance 2008). Our innovation output indicators include the dummies for product and service innovations, share of sales due to new products in total sales, share of exports in total saleand firms' self-reported innovation impacts. The latter includes in total nine different possible impacts, including both product-oriented impacts (increased choice, improved quality, enlargement of market) and process-oriented impacts (increased productivity, reduction of labor costs, and increased flexibility in production). Thus, our output indicators includes both.

[2] For example, according to Eurostat, in CIS3 only 6% of the innovative firms in Estonia had received public support, while the unweighted average for EU15 was 26%; in CIS4 the numbers were 10 and 31%.

The individual innovation indicators are combined into composite indicators via the use of factor analysis. Our factor analysis consisted of the following steps.

- We first extracted the factors for the innovation inputs, process innovations, and innovation outputs and outcomes. For each three, the factors have been chosen so that the eigenvalues are more than unity and factors individually contribute to the variance in data more than 10%. Each factor is defined as a bulk of coefficient called factor loadings that measure the correlation between individual indicators and latent variables. We have used the principal-component analysis in order to extract the factors.
- As the second step, the factors were rotated in order to simplify their interpretation. We have used the Varimax method which attempts to minimize the number of variables having high loadings in a particular factor.
- The composite indicators for inputs, processes and outputs have been calculated by weighting each factor with the respective share in the explained variance in the data set (i.e., the normalized sum of squared loadings); this approach was used for instance, also by Nicoletti et al. (2000). Concerning alternative approaches, Carayannis and Provance (2008) calculated the composite factors as the unweighted sum of individual factors. Yet another approach would be to use an entropic function with normalized squared factor loadings.

As mentioned above, the purpose of the paper is to link the innovative behavior with the path dependency. Among the many possible indicators, for the latter we have decided to assess the path dependency of a sector assessed on the basis of the average level of value-added per employee in a respective industry in the beginning of the analyzed period, and the changes in competitiveness are assessed by the change in the value-added per employee in respective industry as on the following scheme. We have used, in the paper, the value added as it has been calculated by the Statistical Office of Estonia.[3]

To analyse the changes in value added, the concept of nominal value added is used, because the intercountry comparison of industries is relevant (and using direct-deflation method would not change the positions of different industries), and also the interpretation of real value added would be doubtful for the purposes of this paper if double-deflation method would be used (see Meade 2007 for a critical review).

The differences across the propensity and output (outcome) of innovativeness in firms are compared in different groups as in Fig. 1.3 (labeled from A to D) by using ANOVA. The average values of the factors and composite innovation indicators are calculated for each two-digit industry. The thresholds for grouping the two-digit industries into the four groups are the respective average values of valued added per employee and its growth rate in the total economy.

[3] The particular formula is as follows: Value added = sales + other business revenues (excl. profits from sales of the capital assets) – total costs – other business costs (excl. losses from sales of the capital assets) + labor costs + depreciation + change in stock of the finished and unfinished products within a year + capital assets produced for the own use.

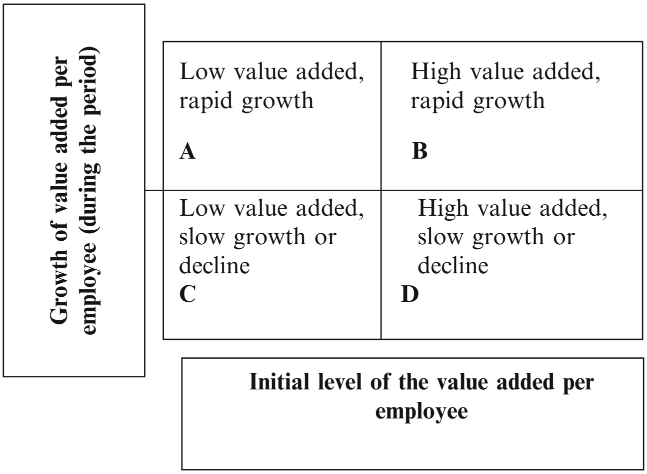

Fig. 1.3 Classifying industries into groups by the initial level and growth rate of the value added per employee. Source: compiled by the authors

1.5 Results

1.5.1 Factor Analysis of Innovation Indicators

The results of the factor analysis of innovation inputs, processes and outputs are presented in Tables 1.1–1.3. The tables present the factor loadings of individual indicators. Let us start with the factor analysis of innovation input variables. As we can see from Table 1.1, three quite different factors are emerging. The first one can be labeled as cooperation (or knowledge) factor, because it is most closely connected with the indicators about the internal and external knowledge sources used for innovation. This factor expresses the interactive learning with other actors in the knowledge infrastructure permitting the SME firms (which most of Estonian firms are) to overcome the resource-based constraints for innovative activities. The second factor reflects the barriers for the innovation of domestic firms related to the lack of finances, too costly innovation projects, and lack of competent personnel. The negative loading of the dummy for foreign firm is the reason why we have hereby labeled this factor as the barriers of domestic enterprises. Third factor reflects not only the investment capabilities of firms into innovation activities, for instance, investments into capital assets, machinery, and equipment, but also expenditures on internal as well as external R&D and knowledge acquisition.

From the process indicators, two factors emerge (see also Table 1.2). The first factor is related to the nontechnological or soft innovations, such as innovations in general work organization and management, relational innovations and marketing

Table 1.1 Factor analysis of innovation input variables

	Factor 1		Factor 2		Factor 3	
	Innovation cooperation		Innovation barriers		Capability to invest	
Interpretation	Factor loadings	Weights of variables in factor	Factor loadings	Weights of variables in factor	Factor loadings	Weights of variables in factor
Capital investments	–0.01	0.00	–0.09	0.00	0.88	0.43
In house R&D costs per employee	0.03	0.00	0.08	0.00	0.06	0.00
Extramural R&D costs per employee	0.08	0.00	0.09	0.00	0.18	0.02
Purchasing costs of machinery and equipment	–0.02	0.00	0.01	0.00	0.88	0.43
Purchasing costs of other external knowledge	0.07	0.00	0.14	0.01	0.12	0.01
Dummy for foreign firm	0.13	0.01	–0.28	0.04	–0.08	0.00
Dummy for public R&D funding	0.09	0.00	0.22	0.03	0.34	0.07
Sources of information						
Sources within the firm or other firms within the group	0.40	0.08	–0.08	0.00	0.14	0.01
Suppliers	0.37	0.07	–0.07	0.00	0.14	0.01
Customers	0.54	0.14	–0.01	0.00	–0.08	0.00
Competitors	0.54	0.14	0.09	0.00	–0.12	0.01
Consultants	0.46	0.10	0.07	0.00	0.06	0.00
Universities	0.51	0.13	0.05	0.00	0.04	0.00
Conferences	0.57	0.16	0.12	0.01	–0.05	0.00
Guilds	0.55	0.15	–0.03	0.00	–0.01	0.00
Obstacles to innovation						
Lack of appropriate sources of finance	0.08	0.00	0.66	0.23	–0.11	0.01
Innovation cost too high	0.06	0.00	0.75	0.29	–0.04	0.00
Lack of qualified personnel	–0.04	0.00	0.57	0.17	–0.03	0.00
Difficulty in finding cooperation partners	–0.02	0.00	0.61	0.20	–0.02	0.00
Weights of factors in summary indicator	0.25		0.36		0.39	
Eigenvalues	2.13		1.89		1.71	
Total variance explained	30.2					

Note: the shaded areas show to which factors the particular individual indicators contribute the most. The results presented herein are based on rotated component matrix. Weights of variables in factor are the normalized squared factor loadings. The weights of factors in summary indicator are the normalized sum of squared factor loadings

Table 1.2 Factor analysis for process innovation variables

	Factor 1		Factor 2	
	Nontechnological process innovation		Technological process innovation	
Interpretation	Factor loadings	Weights of variables in factor	Factor loadings	Weights of variables in factor
New or improved producing method	0.06	0.00	0.78	0.35
New or improved delivery method	0.27	0.03	0.57	0.18
New or improved supporting activity of production	0.21	0.02	0.75	0.33
New or improved knowledge management system	0.64	0.18	0.36	0.08
A major change to the organization of work	0.69	0.21	0.26	0.04
New or improved way of communication with other firms	0.70	0.22	0.16	0.01
Changes to the design or packaging of goods and services	0.53	0.12	0.15	0.01
New or significantly changed sales or distribution method	0.68	0.21	0.00	0.00
Weights of factors in summary indicator	0.56		0.44	
Eigenvalues	2.98		1.00	
Total variance explained	49.8			

Note: the shaded areas show to which factors the particular individual indicators contribute the most. The results presented herein are based on rotated component matrix. Weights of variables in factor are the normalized squared factor loadings. The weights of factors in summary indicator are the normalized sum of squared factor loadings

innovations, and also design. The second factor comprises more technological innovations, namely changes in production methods or technologies and auxiliary process innovation and changes in logistics.

Table 1.3 reflects the results of innovative activities of firms. These results are expressed by three factors: The first factor (F1) reflects general impact of product and process related innovations. In this factor, the indicators such as new market or expanded market share, improved quality of products and services, increased flexibility of production processes, reduced labor and material costs, increased productivity, reduced environmental impacts and better alignment to the regulations are included. The second factor (F2) reflects the commercialization success of new products by indicators of the share of the sales from new to market and new to firm products, and also the increased range of goods and services. The last factor (F3) comprises only indicator of export propensity (share of exports in sales), which seems to be a separate category.

Table 1.3 Factor analysis for innovation output and outcome variables

	Factor 1		Factor 2		Factor 3	
	Impact of innovations		Product innovations and commercialization		Exporting	
Interpretation	Factor loadings	Weights of variables in factor	Factor loadings	Weights of variables in factor	Factor loadings	Weights of variables in factor
Dummy for new goods	0.13	0.00	0.84	0.20	–0.01	0.00
Dummy for new services	0.17	0.01	0.66	0.13	–0.26	0.06
Share in sales of goods and services new to enterprise	0.09	0.00	0.82	0.19	0.05	0.00
Share in sales of goods and services new to market	0.16	0.01	0.80	0.19	0.12	0.01
Share of export in sales	0.03	0.00	–0.02	0.00	0.92	0.79
Effects of innovative activities						
Increased range of goods and services	0.18	0.01	0.71	0.15	–0.24	0.05
New market or expanded market share	0.50	0.07	0.46	0.06	–0.22	0.04
Improved quality	0.65	0.12	0.34	0.03	–0.10	0.01
Increased flexibility	0.58	0.09	0.20	0.01	–0.11	0.01
Reduced labor costs	0.78	0.17	0.08	0.00	0.06	0.00
Reduced material costs	0.70	0.14	0.09	0.00	0.11	0.01
Reduced environmental impacts	0.68	0.13	0.10	0.00	0.05	0.00
Better alignment to the regulations	0.57	0.09	0.26	0.02	0.02	0.00
Increased productivity	0.76	0.16	0.18	0.01	–0.03	0.00
Weights of factors in summary indicator	0.48		0.37		0.15	
Eigenvalues	5.14		1.94		1.02	
Total variance explained	30.2					

Note: the shaded areas show to which factors the particular individual indicators contribute the most. The results presented herein are based on rotated component matrix. Weights of variables in factor are the normalized squared factor loadings. The weights of factors in summary indicator are the normalized sum of squared factor loadings

1.5.2 The Differences in Innovative Behavior Across Sectors

As we decided to use the initial level of value added of an industry as the proxy for the path dependency, all analysed industries were grouped into four groups according to two indicators – the initial level of value added per employee (labor productivity) and the changes in this variable:

- Group A – low value added per employee and its relatively rapid increase.
- Group B – high value-added per employee and its relatively rapid increase.

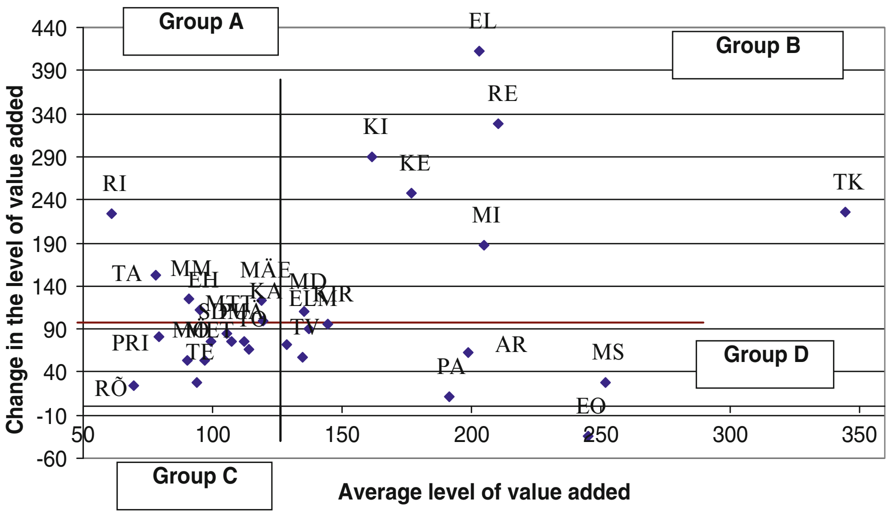

Fig. 1.4 The initial level and dynamics of value added per employee in 2000–2005 by industries (in thousands of EEK). The *lines* in the figure represent average levels of indicators in Estonian economy. The sectors shown in italic have changed the group compared to the analysis of residual income

- Group C – low value added per employee and its relatively slow growth.
- Group D – high value added per employee and its relatively slow growth.

The groups were separated by using the average indicators of Estonian economy at the place of threshold values. Different positions of the sectors are shown in the Fig. 1.1.[4]

The results in the Fig. 1.4 show that the large number of sectors has been located around the average indicators and the differences between them are small (detailed typology of industries into four groups is given in Appendix 2). In group A are sectors with the low initial level and rapid growth in value-added – research and development (TA); recycling (RI); machinery (MM), mining (MÄE), construction (EH); and wholesale and retail trade (KA).

In group B, the sectors with high initial level and rapid subsequent growth in value added are included, including electricity, gas and water supply (EL), renting of machinery and equipment (RE), transport and communication (TK), real estate (KI), chemical industry (KE) and production of nonmetallic mineral products, which mainly contains construction material production (MI). The closest to the average indicators in this group is manufacture of medical and optical equipment (MD). In this group, the direct impact of cyclical behaviour of the economy (construction, construction materials, renting of machinery and chemical products) as well as the indirect impact through increased domestic demand (energy, telecommunication), can be revealed.

[4] For the sake of persistence analysis of the groups, the similar analysis was conducted on the basis of residual income of firms. Residual income has been measured hereby as value added minus labour costs minus depreciation expenditures. However, the general picture was not different, only some sectors changed their positions.

Table 1.4 The average values of innovation input indicators in different groups of industries

Group		Input factor 1: cooperation	Input factor 2: low innovation barriers	Input factor 3: capability to invest	Composite input indicator
A	Low value added per employee, rapid growth	0.15	0.24	–0.03	0.12
B	High value added per employee, rapid growth	–0.05	0.06	0.24	0.08
C	Low value added per employee, slow growth	–0.06	–0.11	–0.15	–0.10
D	High value added per employee, slow growth	0.18	–0.10	–0.12	–0.01
	F-statistic	0.55	1.38	4.72	1.49
	P-value	0.65	0.27	0.01	0.24

Note: F-statistic reported in the table shows whether the means of the groups are statistically significantly different from each other

Group D is characterized by the high initial level, but slow subsequent growth of value added. The group consists of computer-related activities (AR), pulp and paper production (PA), publishing (KIR), plastic production (KU), office machinery and computers (EO), motor vehicles and trailers production (MS), manufacture of electrical machinery and apparatus (ELM), and transport equipment production (TV).

The most problematic situation can be seen in sectors in group C. Stemming from the low value added per employee, they are characterized by the low investment capabilities; at the same time, the situation is not going to be improved in the future because the growth of value added is also slow. Vicious circle emerges – there are objective needs for transforming the activities, maybe the entire business model, but there are no financial means for doing that. This group comprises mostly of the traditional industries, which are as well the largest exporters – agriculture and forestry (PRI) production of wearing apparel (RÕ), textiles (TE) and furniture (MÖ); and manufacture of wood products (PU), food products and beverages (TO), basic metals (MET) and fabricated metal products (MTT).

As the next step the differences in innovation behavior across those identified groups (A to D) were analysed. For this purpose, Tables 1.4–1.6 were constructed, which present the average levels of input, process and output factors by all four groups of sectors. In addition also by all three groups of factors the composite indicator was calculated using weights.[5] Table 1.4 gives us the results about the factors of innovation input indicators – the cooperation (intensity of using various sources of knowledge), capability to invest and innovation barriers, to some degree, are also reflection of the previous development path of the sectors. Table 1.4 reveals

[5] The weights of factors in summary indicator are the normalized sum of squared factor loadings.

Table 1.5 The average values of innovation process indicators in different groups of industries

Group		Process factor 1: nontechnological innovation	Process factor 2: technological innovation	Composite indicator of processes
A	Low value added per employee, rapid growth	–0.15	–0.11	–0.13
B	High value added per employee, rapid growth	0.25	–0.08	0.11
C	Low value added per employee, slow growth	–0.01	0.05	0.01
D	High value added per employee, slow growth	0.26	0.15	0.21
	F-statistic	0.86	0.59	1.10
	P-value	0.47	0.63	0.37

Note: F-statistic reported in the table shows whether the means of the groups are statistically significantly different from each other

Table 1.6 The average values of innovation output indicators in different groups of industries

Group		Output factor F1: impact of innovations	Output factor F2: product innovation and commercialization	Output factor F3: exporting	Composite indicator of innovation outputs
A	Low value added per employee, rapid growth	–0.19	–0.17	0.09	–0.15
B	High value added per employee, rapid growth	0.16	–0.03	–0.55	–0.02
C	Low value added per employee, slow growth	0.07	–0.11	0.16	0.00
D	High value added per employee, slow growth	–0.15	0.44	–0.18	0.10
	F-statistic	1.57	2.07	2.16	0.80
	P-value	0.22	0.13	0.12	0.50

Note: F-statistic reported in the table shows whether the means of the groups are statistically significantly different from each other

that innovation barriers are high by these sectors (C and D) where the growth rate of value added per employee has been the slowest (regardless of its initial level).

At the same time cooperation factor was highest by the group A with high growth of value added as well by group D with high initial level of value added. Resources dedicated to innovation (capability to invest) have been the highest in group B with initially high level of value added and its subsequent rapid growth. By looking at the composite input indicator, it had the largest positive value in groups A and B where the level of value added was either low but growing rapidly or high but growing slowly.

Table 1.5 presents two factors synthesizing the innovation process indicators – technological- and nontechnological innovation. In groups B and D with high initial

Table 1.7 The average values of innovation input, process and output indicators in different groups of industries

Indicator	Groups of economic sectors/industries					
	A	B	C	D		
	Low VA, rapid growth	High VA, rapid growth	Low VA, slow growth	High VA, slow growth	F-statistic	*P*-value
Innovation input factors						
Input F1: cooperation	0.15	−0.05	−0.06	0.18	0.55	0.65
Input F2: low innovation barriers	0.24	0.06	−0.11	−0.10	1.38	0.27
Input F 3: capability to invest	−0.03	0.24	−0.15	−0.12	4.72	0.01
Innovation process indicators						
Process F1: nontechnological innovation	−0.15	0.25	−0.01	0.26	0.86	0.47
Process F2: technological innovation	−0.11	−0.08	0.05	0.15	0.59	0.63
Innovation output indicators						
Output F1: impact of innovations	−0.19	0.16	0.07	−0.15	1.57	0.22
Output F2: product innovation and commercialization	−0.17	−0.03	−0.11	0.44	2.07	0.13
Output F3: exporting	0.09	−0.55	0.16	−0.18	2.16	0.12

level of value added (in both, with rapid or slow growth), the nontechnological innovation is clearly dominating. High importance of technological innovations is associated with the slow value added growth (groups C and D). By the composite index group D is by far the strongest using both process innovations.

Table 1.6 presents the average values of factors about the innovation output indicators. It is interesting to see how the groups A and D, with high growth and high initial level of value added, do not feel that they benefit from innovation – the value of F1 impact of innovations is negative. Product innovation and commercialization is used highly in sectors with initial high level of value added (group D). All other groups have negative values by F2. Third output factor F3 indicates that exporting sectors are with low level of value added (groups C and A) reflecting from one side the rapid growth of costs, but slow growth of revenues. Nonexporting groups are with high value added (slow or rapid growth), which indicates that domestic market orientation has allowed to benefit in value added growth.

In order to understand better how different aspects of innovation behavior are combined across four groups of sectors, Table 1.7 was designed. It contains average values of all eight identified synthetic factors – three on indicators of innovation input, two about process and three on output indicators. By taking the indicators together, one can say that sectors forming the group A are not strongly focused on innovation, because the input, process and innovation output indicators are weak. The major strength of those sectors lies in the low barriers to innovation and good cooperation. Rapid growth in value added results either from the innovations in previous periods, other factors (e.g., construction boom[6]), or relatively weak starting position (as is the case of recycling).

In the case of group B, the path dependency is evident by the initially high level of value added and also in high capacity to invest. It allows us to concentrate on the nontechnological innovations and ensure high growth rates of value added on domestic market remaining at the same technological level (see negative value of technological innovations). By looking more closely at the components of the barrier factor, the lower barriers stem probably from the relatively higher importance of foreign investments in those sectors (electronics, construction materials, and chemical products). The impact of innovations has been assessed to be relatively high in this group; however this is not reflected in the strong commercialization indicators (meaning that most of the growth in value added stems from selling the traditional, unchanged products).

Group C is characterized by the very low level of input factors. This group has the lowest investments into innovation having at the same time strong barriers for innovation. Concurrently, the process innovations are also less conducted in this group. This kind of noninnovative behavior is characteristic to the traditional exporting sectors such as textiles, wood products, furniture, metal and metal products, and part of the electronics industry. The sustainability of the industries is under serious question.

Group D has low investment capability and strong barriers to innovation. Paradoxically, the process innovation indicators are the strongest (both technological and nontechnological) and product innovation and commercialization factors as well. The strength of process innovation stems from the investments into machinery and equipment, which are possibly not separable from many investment components in the factor. Several sectors in this group (machinery, electronics, rubber, and plastics) have also been gaining from the increased domestic demand during 2000–2005. However, in general group D has innovation behavior, which allows in the medium run to improve their value-added content.

1.6 Conclusions

The current paper was targeted to figure out, which are the differences between sectors in Estonia in their innovative behavior and how those differences could be explained by the previous development of those sectors/industries or how does path

[6] The construction booms was caused by the growing real estate prices and the strong demand for real estate caused by low interest rate and easy access to loans after joining with EU. The construction volume index calculated by the Statistical Office of Estonia rose during 2005–2007 by 87%.

dependency matters. It means that actually we wanted to investigate, whether the different dynamic capabilities in sectors will be manifested in the design of different upgrading strategies involving various types of innovative behavior.

The analyses of innovative behavior were executed on the data from the Estonian Community Innovation Survey IV that covers the years 2002–2004. Indicators of innovation behavior were divided into three groups – innovation input, process and outcome indicators. With the help of factor analysis, the whole set of innovation indicators was compressed into eight synthetic factors. The initial level of value added and its growth was taken as proxies for the path dependency. Sectors were divided into four groups according to their initial level and growth of value added.

The next part of the analyses was trying to find certain regularities between the innovation behavior of sector and factors presenting innovation input, process and outcome. Results of the analysis supported the idea that the innovative behavior of different sectors was really very heterogeneous and the initial level and the speed of growth of value added matter. In very general terms the innovative behavior of industry groups with low initial value added level was weak. But looking more precisely, the two industry groups with initially low value-added level (previous development path has produced weak starting position) behave rather differently. In one group of industries (A) the high level of cooperation and low barriers of innovation combined with high propensity to export resulted in the rapid growth of value added, but it happened despite that they were very weak in innovation process. In the second group of industries with low initial level of value added (C), all innovation input factors were extremely low and their major attempt was to execute process innovations in order to be able to continue to export. In Fig. 1.5 this is indicated as the shift upwards to the new level of productivity of technological processes. The conclusion from these two groups could be that initial value-added level combined with the innovation input indicators gives rather good understanding about the different speed of growth of the value added in those groups. From the viewpoint of policy implications, it insists the need for the targeted approach towards different groups of sectors, e.g., the innovation cooperation need to be addressed much more in case of group C sectors compared with group A.

Inside the groups with initially high level of value added (B and D) the further growth in value added has been possible primarily due to the nontechnological innovations; a lesser percentage of the growth has resulted from the technological innovations (group D). In Fig. 1.5, the innovation behavior of group B is shift to the right towards nontechnological innovations and for the group D, shift to left and upwards towards product innovations and commercialization and also technological process innovations. However, common feature for the both groups is their domestic market orientation. The growth of value added in group B does not originate from innovative products; therefore, the rapid growth is not sustainable. Therefore, policy implications should be to address this issue by providing policy measures, supporting and facilitating internationalization in those groups.

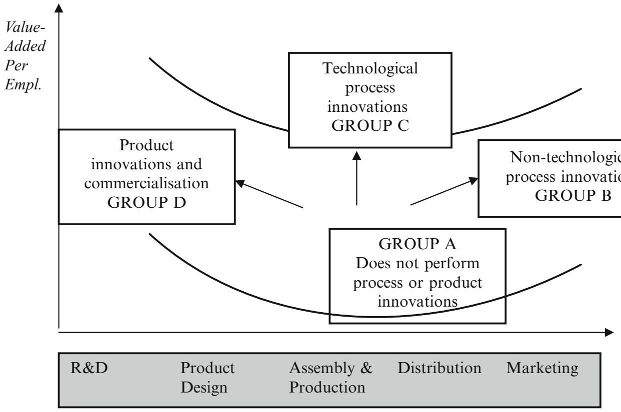

Fig. 1.5 The innovative behavior of four groups of Estonian sectors/industries on the value chain map

Appendix 1 Definitions and summary statistics of variables used in descriptive tables and regression analysis

_varname	meancis4	sdcis4	sort	mincis4	maxcis4	n	sumn
capinvest	48.31541	115.9843	1	0.014671	2335.597	1	36
rdintexp_emp	12.10306	112.8228	2	0	3097	1	36
rdoutexp_emp	1.997356	12.58385	3	0	225	1	36
maschexp	37.84372	178.5635	4	0	3818	1	36
extknowexp	0.829532	4.637571	5	0	72.22222	1	36
for	0.199255	0.399564	6	0	1	1	36
inno_grant_public	0.057241	0.232369	7	0	1	1	36
inno_coop_firm	0.090441	0.286894	8	0	1	1	36
inno_coop_supp	0.140813	0.347928	9	0	1	1	36
inno_coop_client	0.133372	0.340073	10	0	1	1	36
inno_coop_comp	0.09731	0.296464	11	0	1	1	36
inno_obst_fin	0.519748	0.499753	12	0	1	1	36
inno_obst_cost	0.38237	0.486105	13	0	1	1	36
inno_obst_pers	0.417859	0.493348	14	0	1	1	36
inno_obst_coop	0.217516	0.412674	15	0	1	1	36
innoprocess_manu	0.250716	0.433549	16	0	1	1	36
innoprocess_deliv	0.091013	0.28771	17	0	1	1	36
innoprocess_support	0.22324	0.416537	18	0	1	1	36
innoorg_know	0.246709	0.431219	19	0	1	1	36
innoorg_rel	0.230109	0.421023	20	0	1	1	36
innoorg_work	0.342301	0.474616	21	0	1	1	36
innomarket	0.259874	0.438691	22	0	1	1	36
inno_good	0.294791	0.456079	23	0	1	1	36
inno_serv	0.174585	0.37972	24	0	1	1	36
inno_newsales_sales	0.092834	0.208934	25	0	1	1	36
inno_newsalesm_sales	0.044256	0.119232	26	0	1	1	36
export_sales	0.40076	0.397241	27	0	1	1	36
inno_impact_choice	0.184316	0.387853	28	0	1	1	36
inno_impact_market	0.169433	0.375242	29	0	1	1	36
inno_impact_quality	0.184316	0.387853	30	0	1	1	36
inno_impact_flex	0.111048	0.314281	31	0	1	1	36
inno_impact_prod	0.119061	0.323953	32	0	1	1	36
inno_impact_labcost	0.082427	0.275093	33	0	1	1	36
inno_impact_mat	0.062393	0.241937	34	0	1	1	36
inno_impact_env	0.051517	0.221113	35	0	1	1	36
inno_impact_legal	0.084717	0.278539	36	0	1	1	36
cis	41	42					36

Indicators of Inputs

Capital investments: 1995–2004
Employees: (the logarithm of) the number of employees in years 1995–2004
R&D costs: in house R&D costs per employee
External R&D: R&D costs purchased outside
Machinery: purchasing costs of machinery and equipment
Other external knowledge: purchasing costs of other external knowledge
Foreign: binary variable (=1 if foreign ownership is present and 0 if not)
PS_support: binary variable (=1 if firm received innovation support from public sector)

Sources of Knowledge for Innovation

All those variables can take 4 values according to the importance of cooperation activities for innovation (0 – not used, 1 – low importance, 2 – medium importance, 3 – high importance):

S_internal_concern: internal or concern knowledge sources are used
S_suppliers: suppliers of equipment, materials, components of software
S_customers: clients or customers
S_competitors: competitors and other firms from the same industry
S_consultants: consultants, enterprises offering R&D services
S_RD: public R&D institutions
S_universities: universities and higher schools, their units and institutes
S_conf_fairs: professional conferences, meetings, fairs, exhibitions
S_journals: scientific and trade journals
S_associations: professional and industry associations

Barriers to innovation. All those variables can take 4 values (0 – no barrier, 1 – low barrier, 2 – medium barrier, 3 – high barrier):

B_risk: excessive perceived economic risks or uncertain demand
B_nofinance: lack of appropriate sources of finance
B_labor: lack of qualified personnel
B_consumer: lack of customer responsiveness to new goods or services
B_technknow: lack of information on technology
B_marketknow: lack of information on markets
B_cost: innovation costs are too high
B_partners: difficulty in finding cooperation partners
B_market: market is dominated by established firms

Process Indicators

Manufacturing process innovation: binary variable (=1 if the firm implemented new or significantly improved production method of goods and services).

Delivery process innovation: binary variable (=1 if the firm implemented new or significantly improved logistics, delivery or distribution method of goods and services).

Supporting activity innovation: binary variable (=1 if the firm implemented new or significantly improved maintenance system, purchasing, accounting or computing method of goods and services).

Knowledge management innovation: binary variable (=1 if the firm implemented new or significantly improved knowledge management system).

Organizational innovation: binary variable (=1 if the firm implemented new or significantly improved way of work organization).

Relational innovation: binary variable (=1 if the firm significantly changed the relations to other firms or public institutions).

Design innovation: binary variable (=1 if the firm implemented new or significantly improved design or packaging method).

Marketing innovation: binary variable (=1 if the firm implemented new or significantly improved sales or distribution method).

Output Indicators

Product innovation: binary variable (=1 if product innovation was conducted).
Service innovation: binary variable (=1 if product innovation was conducted).
Share of new products: share of new to the market products in turnover.
Export share: share of export in turnover in 1995–2004.

Effects of innovative activities (3 = high degree of observed effect, 2 = medium degree, 1 = low degree, 0 = not relevant):

E_range: Increased range of goods and services.
E_market: New market or expanded market share.
E_quality: Improved quality of goods and services.
E_fexibility: Increased flexibility of production or service provision.
E_productivity: Increased productivity.
E_labor_costs: Reduced labor costs per unit of production.
E_material_costs: Reduced material per unit of production.
E_Envir: Reduced environmental impacts or improved health and safety.
E_Regul: Better alignment to the regulations.

Appendix 2 Value added per employee in 2000 and its change between 2000 and 2005 in various industries of the Estonian economy

Industry	Abbreviation on Fig. 1.3	Change in value added per employee during 2000–2005 (in thsd.EEK)	Value added per employee in 2000 (in thsd.EEK)	The grouping of industry according to the initial level and change of value added
Research and development	TA	152.9	78.2	A
Wholesale and retail trade; repair of motor vehicles, motorcycles, and personal and household goods	KA	99.3	119.6	A
Recycling	RI	224.7	61.1	A
Manufacture of machinery and equipment n.e.c	MM	125.7	90.9	A
Mining and quarrying	MÄE	123.3	119.1	A
Construction	EH	112.7	95.1	A
Transport, storage, and communication	TK	226.4	344.9	B
Real estate activities	KI	290.6	161.4	B
Electricity, gas and water supply	EL	412.1	203.2	B
Renting of machinery and equipment without operator and of personal and household goods	RE	328.9	210.5	B
Manufacture of chemicals, chemical products, and man-made fibers	KE	247.3	176.8	B
Manufacture of medical, precision and optical instruments, and watches and clocks	MD	110.2	135.2	B
Manufacture of other non-metallic mineral products	MI	188.1	205.0	B
Manufacture of wearing apparel; dressing and dyeing of fur	RÕ	24.5	69.5	C
Agriculture, hunting and forestry	PRI	81.4	79.0	C

(conitnued)

Appendix 2 (continued)

Industry	Abbreviation on Fig. 1.3	Change in value added per employee during 2000–2005 (in thsd.EEK)	Value added per employee in 2000 (in thsd.EEK)	The grouping of industry according to the initial level and change of value added
Manufacture of radio, television and communication equipment and apparatus	SD	75.0	99.4	C
Manufacture of textiles	TE	28.2	94.2	C
Furniture	MÖ	53.1	90.3	C
Other business activities	MÄ	76.3	112.4	C
Manufacture of food products and beverages	TO	67.0	114.3	C
Manufacture of wood and wood products	PU	75.5	107.7	C
Manufacture of fabricated metal products, except machinery and equipment	MTT	84.1	105.3	C
Manufacture of basic metals	MET	54.3	96.9	C
Manufacture of pulp, paper, and paper products	PA	11.3	191.8	D
Manufacture of electrical machinery and apparatus n.e.c.	ELM	89.4	137.3	D
Real estate activities	KIR	96.2	144.7	D
Computer and related activities	AR	63.5	199.1	D
Manufacture of other transport equipment	TV	57.2	134.9	D
Manufacture of office machinery and computers	EO	−34.2	245.2	D
Manufacture of motor vehicles, trailers, and semitrailers	MS	27.5	252.1	D
Manufacture of rubber and plastic products	KU	71.9	128.4	D
Total economy		98.4	126.3	

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Chapter 2
Factors Affecting the Performance of New Product Development Teams: Some European Evidence

Klas Eric Soderquist and Konstantinos Kostopoulos

2.1 Introduction

New product development (NPD) often necessitates activities that are performed by different departments or units within the same or between different organizations. To counteract coordination and communication problems that may arise across unit boundaries, many enterprises introduce cross-functional NPD teams[1] to direct and control the development process. However, and despite teams' importance for generating innovation, there is a relative lack of attention paid to the innovation processes that occur *within* organizational teams (Anderson et al. 2004). Most studies focus on individual, organizational, or even interorganizational-level conceptualizations to examine innovation in organizations (Kogut and Zander 1992; Smith et al. 2005), thus failing to identify the crucial role that teams play during innovation development. This is quite surprising, since teams are considered a fundamental learning and innovation development unit within an organization (Senge 1990; Van de Ven et al. 1999). As Rousseau and House (1994) have noted, a team-level or "meso" perspective is inherently integrative, by incorporating innovation factors from two or more levels simultaneously.

Furthermore, there is notable variation across organizations with respect to how those NPD teams are designed, formed, and managed. For example, existing research (e.g., Ancona and Caldwell 1992b; Reagans and McEvily 2003; Mathieu

[1] The terms "team" and "group" will be used interchangeably in this study, referring to a collection of individuals that exist within an organizational context, have clearly defined membership, and interact and share responsibility for the accomplishment of a common goal or task (Hackman 1987).

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et al. 2008) indicates several factors that could affect the NPD teams' performance, including team size, composition, structural configuration, process and psychological characteristics, leadership behaviors, and support of the organizational environment. The literature, however, lacks integrative representations of these factors with adequate evidence that substantiate their relevance for NPD teamwork.

The objective of the present work is to address these open issues in the literature. To this end, we review those factors that exert important influences on the functioning and performance of NPD teams, and we illustrate their relevance by providing concrete evidence from large European organizations that actively engage in collaborative NPD. These illustrations are extracted from Innovation Impact, a major research project focusing on collaborative R&D comprising over 70 detailed case studies from all over Europe (Polt et al. 2008).

2.2 Designing NPD Teams

NPD projects could differ in the way they are designed and managed based on the nature of the task they undertake (Cohen and Bailey 1997; Rothaermell and Deeds 2004). Rothaermell and Deeds (2004) distinguished two basic types of NPD projects: (a) projects that explore new opportunities and (b) projects that exploit existing capabilities. Exploration denotes search and experimentation with new opportunities, while exploitation refers to the efficiency and refinement of current resources and skills (March 1991). Despite the differences between those two activities, scholars have suggested that a well-balanced combination of the two types of activities is critical for long-term organizational success (Gupta et al. 2006; Levinthal and March 1993), and in reality, most firms engage in both such activities simultaneously since they participate in several parallel projects that are at different stages in the product development process.

The nature of the task strongly affects how a NPD team will be designed and further organized. In most cases, NPD teams are time-limited, nonrepetitive in nature, and involve considerable application of knowledge, judgment, and expertise. The most well-known typology of NPD teams was advanced by Clark and Wheelwright (1992). According to these authors, four dominant project team categories can be specified, based on their structural characteristics:

Functional teams. Members remain in their functional departments and report to their regular functional manager. Functional teams do not have a formal project manager or a dedicated liaison person, since tasks must be subdivided into separable, independent activities performed by separate departments.

Lightweight teams. Members assigned to a lightweight team reside physically in their functional areas, and functional supervisors retain authority over evaluation and rewards. However, a project manager represents the group, acting as a coordinator of the various functional activities.

Heavyweight teams. In contrast to previous types, the heavyweight manager has direct access to and responsibility for the work of all team members, while she/he is a senior executive that usually outranks functional managers. In most cases, the core heavyweight group is physically colocated, and dedicated to the project on a full-time basis.

Autonomous teams. In this type of team structure, individuals from the different functional departments are formally assigned, colocated, and dedicated full time (and often permanently) to the NPD project. The project manager, a very senior person within the company, is given full control over the resources offered by the different functions and is solely responsible for the contribution and performance of the team's members. Autonomous teams are typically recommended for NPD that has an explorative focus, departing significantly from existing technologies and routines.

An interesting refinement to Clark and Wheelwright's categorization was proposed by Loillier (1999), who focused specifically on innovation-oriented teams to identify three basic team types: (a) the hybrid type, being autonomous in decision making, where standardization, formalization, and functional specialization are at a moderately high level; (b) the organic type, having little autonomy in decision making but great flexibility due to a low level of functional specialization; and (c) the bureaucratic type, which has little autonomy in decision making, average level of functional specialization, and high level of standardization and formalization. It is useful to note that the evidence presented throughout this study concerns mainly NPD of a lightweight structure, being rather autonomous in decision making.

In designing NPD teams, the organization must further consider two fundamental structural features that influence teams' mix of resources and skills and determine the dynamics occurring within the group: team size and composition.

2.2.1 Team Size and Team Composition

NPD teams may range from a few members to hundreds of members. Large-sized teams, however, are not always better performers. As group size increases, there is a greater likelihood of social loafing and free riding, thereby decreasing the extent of creativity and learning in a team (Wong 2004; Gibson and Vermeulen 2003). In addition, large teams can create more administrative and transaction costs, as well as coordination problems, leading to costly delays and communication lags (Ancona and Caldwell 1992a). These disadvantages of large groups, however, have to be weighed against their potential strengths. On the positive side, large teams are likely to have access to a greater amount of resources, skills, abilities, or accumulated experience and knowledge of their members (Mathieu et al. 2008). Hence, an organization needs to balance the skill and knowledge advantages that large groups offer against certain communication and coordination problems that these groups may confront. This delicate trade-off is illustrated in the following example.

The structure and processes of knowledge sharing were referred to by our interviewees as particularly sensitive to the size of the teams. The R&D manager of a large multinational expressed the following problematic: "There is a threshold level somewhere, which is very difficult to predict, above which knowledge sharing no longer occurs naturally. The trade-off is to decide when you must insist on people using formal structures such as Intranets and dedicate someone to oversee the process of knowledge transfer and sharing in general, and when these processes are best left to the natural problem-solving drive in the team." This trade-off illustrates the transaction costconcern; In larger teams, coordination costs occur, which do not necessarily pay back through better knowledge sharing than what can be achieved "for free" in smaller teams.

The selection of the appropriate team size will subsequently impact team composition. Composition refers to the nature and demographic qualities of the team members, constituting one of the most frequently studied team design variables. Attributes such as members' knowledge, skills, experience, educational background, and representativeness of various functional units have been constantly investigated, especially in relation with team effectiveness and success. The typical model of inquiry has been to assess the performance of existing organizational teams over time, and to associate that performance to measured aspects of group composition (Guzo and Dickson 1996).

When referring to team composition, heterogeneity or diversity is a central concept. Using Williams and O'Reilly (1998) as a guide to the many relevant aspects on which individuals differ, diversity can be broadly defined as "…any attribute that people use to tell themselves that another person is different" (Williams and O'Reilly 1998, p. 81). Diversity is traditionally conceptualized in terms of visible differences in age, gender, and race. Individuals may also differ on less visible characteristics such as level of education, functional experience, or tenure within the company. In NPD teams, the level of functional diversity is of great importance. Hence, teams necessitate cross-functional designs, including members from more than one functional area, such as engineering, manufacturing, or marketing. A greater variety of members provides a broader knowledge base and increases the cross-fertilization of ideas. These activities can lead to the creation and improvement of innovative ideas, as well as provide novel solutions to product development problems. Moreover, since NPD teams require entrepreneurial spirit and creative thinking, the diversity advantages are expected to counteract potential risks associated with coordination delays and conflict emergence between people with different functional or educational backgrounds (Van der Vegt and Bunderson 2005). The evidence below demonstrates this problematic.

Collaborative R&D projects increase diversity from the fact that individuals from different organizational practices and cultures are brought together to accomplish common tasks and goals. The Innovation Impact case studies were rich on examples where this diversity was fruitful. "Without the collaboration with [a leading research institute in RFID Technology] we would not have been able to bring our innovative process to the market in such a short time, and with certainty about quality. Their expertise and approach to prototype testing opened new perspectives to us," expressed the CEO of an SME developing systems for industrial maintenance. In addition, from the perspective of a senior researcher in a university research lab, "The collaboration with several SMEs [in the studied project] was a first time experience for us and brought a much needed exposure to entrepreneurial thinking that we had not experienced before in our long-term work with multinationals." There can be a downside to this type of diversity, however. The R&D Director of a medium-sized high-tech component manufacturer stated: "A core capability for us is to speedily introduce new products in the market. Development lead-time is a key success factor. We felt the academic partners never really took this imperative to their heart in this collaborative venture." Hence, diversity can indeed enhance development performance, but can also distort alignment in some cases.

2.3 The Processes and Behavioral Characteristics of NPD Teams

The importance of studying the internal conditions of teamwork has been extensively recommended in the literature as an important step toward revealing the mediating mechanisms that convert inputs into collective team outcomes (e.g., Reagans and McEvily 2003; Hoegl and Gemuenden 2001; Mathieu et al. 2008). Such conditions can be generally grouped into two main categories: (a) process, and (b) behavioral (or emergent) characteristics (Cohen and Bailey 1997; Marks et al. 2001).

2.3.1 Process Conditions

Process characteristics denote social features by which members work interdependently to utilize various resources to yield meaningful team outcomes (Foo et al. 2006; Stewart and Barrick 2000). These team processes principally involve variables such as ties or interpersonal connections (communication frequency, formality, and structure), coordination, boundary-spanning activities, conflict (task, relationship, and process), decision-making practices, and learning dynamics.

The concept of ties was originally coined by social capital and network theorists to denote those aspects related with the structural properties of exchange relationships.

Strength of ties (i.e., communication frequency) is argued to positively influence various team characteristics and outcomes, including cohesion and team spirit, trust, information flows, knowledge creation procedures, problem solving, member satisfaction, project success, and team performance (McFayden and Cannella 2004; Smith et al. 2005). Individuals who communicate with each other frequently or who have strong emotional attachment among themselves are more likely to engage in collective action, and systematically share knowledge than those who communicate infrequently or who are not emotionally attached. Therefore, the quality of social relations can engender individual members to act, exchange information, and create new knowledge, hence facilitating the development of social capital. The importance of social capital – "the goodwill that is engendered by the fabric of social relations and that can be mobilized to facilitate action" (Adler and Kwon 2002, p.17) – for innovation performance has been documented in many instances already (e.g., Hargadon and Sutton 1997; Tsai and Ghoshal 1998; Oh et al. 2004), and an illustration of its importance for successful collaborative R&D is provided below. However, it is still a much neglected factor at the level of day-to-day NPD management and teamwork, even though it is precisely from there it has to be built up.

In many of the Innovation Impact case studies, the reputation of coordinators and/or partners as reliable, knowledgeable, cooperative and efficient managers, and/or R&D partners was frequently advanced as a factor influencing positively project success in terms of innovation or significant new knowledge creation. Either self-estimated by the interviewees, or attributed to other partners, this goodwill, once it has been achieved and as long as it can be sustained, provides a number of advantages to its possessors that also spill over to the collaborating partners and the project itself. These advantages include high probability of being granted relevant projects over time, stronger bargaining power vis-à-vis funding bodies, greater probability of attracting excellent partners to new consortiums, greater facility in making partners adhere and align to project objectives and management structures, and a strong dissemination impact of results due to the presence and the weight of a prestigious-built-on-merit organization. Hence, it is exactly about capitalizing on goodwill built-up in order to facilitate action at the moment and in a particular project.

Coordinator/partner social capital also has the conceptual and policy-making power of bringing together several of the softer issues advanced as essential for project success (e.g., trust, communication, and motivation) and integrate them with the time dimension. This is because social capital building is longitudinal process that can be easily broken due to just a few mishaps in a particular instance. Scientific and technology excellence is a necessary but not sufficient condition for building up this social capital. Complementary factors identified from the cases include commitment to the success of the project as a collaborative effort, openness, fairness, visionary leadership (of project and/or project area), reactivity, and excellent relational sensitivity and skills.

Social capital and communication processes are closely related to coordination practices. Coordination refers to the ongoing endeavor to achieve unity of effort among interdependent organizational subunits performing a given task (Lawrence and Lorsch 1967). NPD coordination involves implementing a project through the mutual exchange of design, knowledge, and other relevant information among interdependent members within and between functional departments or units. There are two forces underlying the need for coordination among team members: task interdependencies and changes occurring during the development process. Task interdependencies arise from the project architecture and refer to the intensity and direction of a workflow relationship among team members. As team members depend on other members' input for accomplishing their own task, the work of an individual member may have implications for the work and progress of the whole team. Therefore, technical details have to be synchronized and connected activities have to be well timed to meet the given schedule and budget constraints. Without effective coordination between members (or sub-teams), interdependencies might produce mistakes necessitating rework and creating crises. The high complexity and uncertainty of development processes, which are exacerbated by the strong interdependencies among sub-teams and frequent changes, can only be dealt with if information is exchanged freely and systematically among the team members. This offers opportunities for negotiations and compromises. Therefore, members need to identify their interrelations and interdependencies with other team members and establish appropriate coordination practices.

As a means of enriching a team's knowledge base, boundary-spanning activities constitute an important process condition determining team performance (Ancona and Caldwell 1992b). Groups that communicate systematically and frequently with people in external entities (e.g., other groups in the organization, academics, colleagues from other firms, suppliers, and clients) are more likely to access a broader array of resources and novel opportunities outside group boundaries (Hansen 1999; Tsai 2001). In this respect, boundary-spanning activities involving political activities, such as negotiating and lobbying resources, represent a critical predictor of managers' and members' ratings of team performance, as well as a source of innovative information that a group seeks to obtain (Edmondson 2003).

In our discussion of team diversity above, operational boundary-spanning activities such as integrated interorganizational problem solving are central to value creation from diversity. Moreover, an important consequence of social capital building is extended bargaining power in relational and "political" boundary-spanning activities. In fact, our case studies showed that a virtuous circle between boundary spanning, diversity, and social capital can materialize in collaborative R&D projects. Operational boundary-spanning activities allow tapping into the potential of value creation from diversity, and when social capital from these interactions and results start to build up, boundary-spanning activities at a relationship building and longer-term strategic level becomes more effective. If the latter leads to an enlargement of the pool of potential collaborators, diversity possible to exploit at the operational level is enhanced and the virtuous circle is renurtured.

Another critical component of a team's social context is conflict – the process resulting from the tension among group members caused by the real or perceived differences, discrepancies, incompatible wishes, or irreconcilable desires (De Dreu et al. 1999). In his pioneering work, Jehn (Jehn 1995; Jehn and Mannix 2001) postulates that even though conflict hinders satisfaction and team performance, task conflict (i.e., differences in viewpoints and opinions regarding the content of the team's task) can be beneficial, since it could enhance cognitive understanding and creative insights when the team works on nonroutine tasks, such as NPD.

The concept of conflict is directly linked with the decision-making procedures followed by a project team. Regardless of top management involvement in decision making, teams can still be distinguished based on the degree to which all members are allowed to participate in decisions. Participative decision making is presumed to enhance group effectiveness by increasing members' sense of responsibility and ownership of the work (Hirst and Mann 2004). However, there is a variety of methods groups can use to make decisions and it is important to use the type of decision-making process that best suits to their needs. Not all problems require full participation, and group decisions can create additional problems rather than solving them. For important decisions, teams might need to reach consensus. The options that teams can use to make decisions may be viewed as lying along a continuum, from leader-based decisions to decisions made with full participation of team members (Johnson and Johnson 1997). Although there are many approaches that a team could use, teams typically use either consultative, democratic, or consensus decision making (Levi 2001). For NPD teams, in particular, more democratic and participative decision-making processes could lead to a thorough understanding of potential complex issues through facilitating information flows and cross-fertilization of ideas, thus enhancing innovation and novelty. Obviously, conflicts can also lead to wrong decisions being made and a sub-optimized result in various operational activities in the NPD process, as illustrated below.

In one of our case studies, a cross-functional interorganizational team lengthily debated and experimented with various versions of a customer needs research questionnaire. The technical expert and his organization supported a specific design of the research instrument, while other team members, with less technical expertise but more "weight" in terms of their accumulated experience and their organization's size and prestige, were skeptical to the suggestions made by the expert and finally ran them over in the ultimate decision-making meeting. As predicted by the expert, the instrument later proved quite useless for any further analysis or use beyond the specific project and had to be redesigned from the beginning in following projects.

Furthermore, researchers have recently argued for the value of learning as a critical team process that leads to new knowledge creation (i.e., in the form of new products, technologies, production processes, or organizational capabilities).

It is also widely recognized that the value generated by an NPD team critically depends on its ability to acquire and assimilate new external knowledge, as well as on the effectiveness of transforming and exploiting current knowledge and skills with the newly acquired knowledge. Within NPD teams, individuals' cognitive schemas are shared, providing guidance to the search efforts team members engage in to enhance innovation activity.

Edmondson (1999) argued that a team's learning behavior consists of activities carried out by members to obtain and process data, which allow the team to adapt and improve. According to Edmondson, team learning, in general, is defined as a process through which a team takes action, obtains and reflects upon feedback, and makes changes to adapt or improve (Edmondson 1999; Argote et al. 2003). To explore further the processes of team learning, Edmondson (2002) distinguished between team behaviors that promote new insights and behaviors that apply (or take action based on) new insights. Regarding the former, sharing information, seeking feedback, discussing errors, and analyzing past performance are key activities. In the latter case activities such as taking decisions, enacting changes and improvements, implementing new ideas, and transferring new information to others in the team are important. These learning behaviors, in turn, facilitate effective performance by allowing the team to shift directions as situations change and discover unexpected implications of team actions (Edmondson 1999). The illustration shows the importance of these learning perspectives in practice.

With very few exceptions, our case organizations emphasized access to new knowledge as a central reason for expanding team-based product development and reinforcing boundary-spanning activities. Most of them were also quite satisfied with the learning outcomes in projects. Good practices for supporting learning included mainstream Knowledge Management activities such as rotation of personnel between projects and the functional duties in order to maximize the learning effect, setting and deploying explicit objectives of extracting knowledge from the projects, and activating resources and processes of technology scanning and watch all along the product development process. A characteristic quote for what our interviewees considered most important comes from a senior engineer in technology consulting company: "Today we need to emphasize soft learning. The level of expertise is generally high among all team members so what becomes critical, especially with increased external collaborations in our customer firms, is to learn how to communicate, listen, adapt and then make decisions that can leverage all this richness of knowledge that various players bring." Relating to the Edmondson typology of team behaviors that promote new insights and those that correspond to actions based on new insights, the soft learning imperative essentially refers to the first type. When information sharing, discussion, and joint analysis become "installed" also at an interorganizational level, the next level becomes to take this integration to the level of decision making and joint strategizing.

2.3.2 *Behavioral Characteristics*

Behavioral traits involve qualities of a team that represent members' attitudes, values, and affection, having a direct impact on outcomes and also indirectly influencing group performance through shaping intra-team processes. Such conditions are primarily concerned with factors such as cohesion and safety or trust.

Cohesion – the degree to which members of the group are attracted to each other, strongly desire to remain in the group and mutually influence one another – has been proposed as an important determinant of group performance and success (e.g., Naumann and Bennett 2000; Webber and Donahue 2001). In cohesive groups, members achieve high levels of interaction and agreement, as well as increased intragroup trust and satisfaction. The basis for such relations is that members identify with the group to such an extent that self-interest is suppressed.

Cohesion is associated with another critical aspect of group psychological conditions, namely safety. Team psychological safety is defined as "a shared belief that the team is safe for interpersonal risk taking" (Edmondson 1999, p.354), such that members will not reject or embarrass those who make mistakes or speak up about difficult issues. It is important to note that limited studies have examined the influence of psychological safety and trust-related constructs on group effectiveness, presenting a rather vague theoretical and empirical view (Ilgen et al. 2005). For example, Edmondson (1999) found that safety enhanced team learning behaviors and performance, while others (e.g., Dirks and Ferrin 2001; Simons and Peterson 2000) demonstrated that while the effects of trust on attitudes and perceptions appeared to be fairly consistent and positive, its influence on behavior and performance is mostly indirect, or even that under high levels of trust and psychological safety group performance is likely to decrease (Langfred 2004).

2.4 Leading and Monitoring the Performance of NPD Teams

The performance of organizational teams is a multidimensional construct, which can be defined as the extent to which a team is able to meet established objectives (Hoegl and Gemuenden 2001). In NPD, specific dimensions of team performance include the adherence to predefined quality, efficiency, and innovativeness (Ancona and Caldwell 1992b; Hoegl and Gemuenden 2001). Quality refers to certain desired properties of the output produced by the team. For an NPD team charged with designing a specific part of a larger product, several properties may be important, including functionality, manufacturability, durability and robustness, dimensional integrity, as well as optical and tactile attractiveness. Efficiency is visualized in terms of the adherence to budget objectives and adherence to schedule objectives. Adherence to budget objectives refers to the costs associated with the team's development activities (i.e., personnel, prototype material, testing, and so on). As for schedule objectives, all groups in a multiteam project are included in an overall sequence of milestones (design reviews and so on) where certain deliverables are expected at predefined times, which, in turn, provide necessary input for other teams. Innovativeness of the team refers to number of new products, processes, or ideas introduced by the team.

Team performance objectives can take many forms (e.g., quantity, speed, accuracy, efficiency, and service to others) but the clarity or specificity of those goals can strongly affect their attainment. In order to combine efforts effectively, team members have to understand jointly what it is they are trying to achieve. Much research also indicates that involvement in goal setting fosters commitment to those goals (Locke and Latham 2000) and consequently better group performance. Moreover, scholars have also directed their attention toward understanding the mechanisms through which objectives impact group outcomes. Weingart (1992), for example, argued that members' effort and quality of the planning process mediated the effect of goal difficulty on performance, and found that group goals raised member effort, which translated into greater team performance. Moreover, Katzenbach and Smith (1993) reported that the existence of clear, unambiguous goals provides benefits pertaining to: the work content of the team's task, the basis for clear communication and constructive conflict among group members, focus on achieving desired outcomes, how members' unique expertise can be best utilized, and the increased motivation of the group. These positive effects of clear strategic goals are illustrated in the example that follows.

Team leaders play a key role in achieving team goals, as well as in monitoring and sustaining a high team performance. Team leaders should be capable of performing a

In an SME dedicated to developing advanced bio-economy and carbon recycling technologies, the power of clear mission, strategy and goals, has been a key success factor for caving out a niche market from a record successful process innovations. Building on its mission "Science to Achieve Results," bridging the gap between research and innovation is an integral part of this company's mission and a main explanatory factor behind its strong innovation focus in all its collaborative R&D activities. Strategically speaking, the company sets its R&D agenda and selects projects only if they fit 100% with its mission and technology development directions. Moreover, it systematically integrates existing or potential customers in the projects, thus ensuring a potential offset market for what is being developed.

Positioned in a high growth but still immature market, the strategy in terms of "where to go" – sustainable lead in environmental technologies with emphasis on recycling– and in terms of "how to get there" – be an innovative solutions provider – reinforces the technology-based innovation focus maintained in project activities. Building on this strategizing process, explicit goals for market penetration and application of new science are set, monitored and continuously stretched. As the entrepreneurs summarized the approach "On our narrow road, we want to be the best, the most concentrated and focused to collect and exploit all the available knowledge in the field."

varied range of leadership behaviors that promote teamwork, organize and direct project work, manage relationships with external stakeholders, and stimulate creativity and innovation (Hirst and Mann 2004). Barry (1991) conducted a detailed qualitative study of engineering and product development teams, and he identified four leadership roles that are critical to ensure teams are able to tackle the challenges of R&D work. On that ground, Yukl (2002) refined this classification to determine four specific roles: boundary-spanning, facilitative, innovation-stimulating leadership, as well as directive leadership. Boundary-spanning leadership involves coordinating the team's task with outside stakeholders, managing outgroup relationships, and negotiating resources and objectives (e.g., with top management executives, suppliers, and users) as well as scanning for information and ideas. Facilitative leadership, on the other hand, refers to whether the leader encourages an atmosphere conducive to teamwork, ensuring that all team members have the opportunity to express their ideas and opinions and participate in group's activities, sharing of valuable information and discussion of different perspectives. A leader who acts as an innovator envisions project opportunities and new approaches by questioning team assumptions and challenging the status quo. Finally, directive leaders drive to structured and ordered performance of project work by communicating instructions, and setting priorities, deadlines and standards. These leadership behaviors can be conceived "behind the scenes" roles that leaders engage in to create a context within which team members function in carrying out the work of a NPD project.

Effective team leadership has been reported as one of the most important vehicles for directing and steering project successfully, especially in those situations concerning a NPD process (Keller 1996). For example, recent studies (e.g., Lovelace et al. 2001) suggest that the characteristics of group leaders significantly affect the work climate and learning in teams, in such a way that leaders may set a positive and safe environment and resolve issues that would otherwise result in extensive, dysfunctional conflict. Cumulatively, these actions are most likely to increase group members' feelings of freedom to express task-related doubts, engage in constructive dialogue, establish trust and collaboration within team, and enhance the application of acquired knowledge (Edmondson 1999).

2.5 The Role of the Organizational Environment

Apart from team-based features, the organizational context within which the NPD team operates exerts substantial influences on its performance and innovation outcomes (Guzo and Dickson 1996). An enabling organizational context relates to team support such as ample resources, information, training, rewards, and a culture encouraging team practices (Anderson et al. 2004). These conditions gain even greater importance in groups with highly conceptual and innovation-oriented tasks (like NPD teams), suggesting that innovation is more likely to occur in contexts where there is support for creativity and novelty, or where innovative attempts are rewarded rather than undervalued. Accordingly, support for innovation can be conceived as the expectation, approval, and practical support of attempts to introduce new and improved ways of doing things in the work environment (West and Anderson 1996).

When analyzing organizational support, it is important to recognize the central role that training and expert assistance hold. Training, acting in most cases as an irreplaceable element of most managerial interventions aiming at improving team operations, has certain beneficial effects on decision making, interpersonal skills, and overall group's technical knowledge (Campion et al. 1993). This becomes even more important in highly innovative group settings, where members seek valuable knowledge and assistance to improve their experimentation and improvization skills, and gain access to all current project-related developments and future plans within the respective organization. Such practices permit more efficient knowledge sharing and exploitation, with direct positive effects on NPD performance (Cannon and Edmondson 2001).

Furthermore, an NPD team must be properly motivated and rewarded in order to achieve superior effectiveness. However, most research on motivation has been conducted mainly to comprehend processes underlying the behavior of individual workers as separate agents. That is, theory and research in work motivation have focused mainly on the individual needs people may have, their own independent goals and expectations, or the personal outcomes they find rewarding. Nevertheless, scientific findings regarding rewards, as a particular aspect of motivation activities, appear to be more advanced. For example, rewards were found to have to significant relationship with manager ratings of team performance, team members' ratings of performance, group productivity, and team process effectiveness (Campion et al. 1993). On the other hand, Cohen et al. (1996) reported that management recognition was positively associated with members' perceptions of performance, trust in management, organizational commitment, and satisfaction. More specifically, when combined with other organizational variables (information access, training, and resources), it proved a positive predictor of team performance. Moreover, Hirst and Mann (2004) supported that the highest performing groups were those whose rewards were in alignment with the teams' tasks.

Finally, a contextual characteristic with distinctive influences on team functioning and performance is organizational climate. Research has suggested that climate perceptions are associated with a variety of important factors at the individual, group, and organizational levels. These include leader behavior (Rousseau and House 1994), turnover intentions (Rentsch 1990), job satisfaction (Mathieu et al. 2008), individual job performance, and organizational performance (Patterson et al. 2005). Scientific work in the field of innovation, in particular, proposes that group climate factors impact levels of innovative behavior in diverse types of teams (West and Wallace 1991; West and Anderson 1996). In this connection, it is reasonable to conclude that climate can affect many different team outcomes, while its dimensions should be carefully analyzed depending on the specific group task and objectives (e.g., flexibility, improvization, scanning, and expert assistance are particularly relevant in innovative project teams – Patterson et al. 2005). To summarize, the positive influence of an enabling organizational context that provides the necessary resources, knowledge, and culture for innovation to flourish is displayed at the following case.

One of the most successful innovation cases in our study was observed in a subsidiary (employing 8000 people in 10 divisions) of a global group present in more than 190 countries. The project, which ended in late 2004, became an independent company in late 2005 with some of the project partners and several new. This company has already closed contracts with two major customers having adopted the high growth potential technology developed through the project. The mobilization of the knowledge, resources and competencies of the large R&D driven multinational was instrumental for this success. The strong focus on R&D and the strategy securing an increasing number of products and services in the group's portfolio from internally generated R&D set the frame and objective of achieving innovation (basically a process innovation) from the initiation and very start of the project. The technology area is characterized by high entry barriers – key technologies cannot be imitated by competitors for a long time, but nevertheless speed of commercialization plays an important role as customers are pushing for integrating the latest technology advances. These industry and market factors played in favor of the presence of a big company with the necessary resource infrastructure and a core competence in commercializing innovation.

In terms of innovation project structure, the company has clear templates for how different kinds of projects are managed for maximized return. The studied project fell into the category of "emerging technologies" that the company develops to the point of marketable products or patents. Moreover, the project was supported by the wide and broad vertical network of the large company and its internal broad portfolio of neighboring technologies and development projects. This made the process innovation well integrated from a producer, user and technology architecture point of view.

2.6 Discussion and Conclusions

A vast amount of scientific work documenting, conceptualizing, and analyzing the significance of innovation and NPD for the survival and success of organizations has been published over the last decade (Nonaka and Takeuchi 1995; Damanpour 1996; Bell 2005). However, and despite the proliferation of studies, our understanding of innovative behavior in organizations still remains relatively undeveloped as the findings appear to be inconsistent and characterized by low levels of explanation (e.g., Drazin and Schoonhoven 1996; Anderson et al. 2004). Such inconsistencies can be partially attributed to a lack of attention on the new knowledge creation and product development processes that occur within organizational teams (Edmondson 2002). In addition, the importance of team conditions (i.e., group design, process, behavioral, and structural factors) and organizational features that support group innovation activities has been largely ignored (Edmondson

1999). The work at hand attempts to inform these open issues in the literature by offering an integrative review of those team and organizational-level factors with the most critical role in the performance of NPD teams. The theoretical overview is supported by evidence from European enterprises that are actively involved in cooperative NPD teamwork.

In this study, we make a fundamental conceptual categorization between team design, process, and behavioral characteristics. The design features refer mainly to trade-offs emerging from choices between large- vs. small-sized teams and between heterogeneous (i.e., diversified) vs. homogeneous teams. Process conditions, on the other hand, involve interdependent team activities (i.e., ties' strength, conflict, participative decision making, and boundary spanning) directed toward organizing taskwork, while behavioral characteristics (i.e., cohesion and psychological safety or trust) reflect affective states and beliefs of team members that vary as a function of team context and processes (Marks et al. 2001). The rationale behind this categorization is rooted in established input–process–output models of teamwork (e.g., Mathieu et al. 2008), which suggest that behavioral conditions do not describe the nature of members' interactions, but rather they can be considered as both inputs and outcomes of team social or design characteristics (Cohen and Bailey 1997).

Regarding design factors, this work, in line with existing research (e.g., Hoegl and Gemuenden 2001; Gibson and Vermeulen 2003), reveals the tensions generated within NPD teams as a result of group size and diversity choices. In particular, we demonstrated that teams should balance the communication and coordination problems that large groups may confront with the limited skills and knowledge base of small group sizes. NPD managers should be very cautious to the transaction cost concern: in larger teams, coordination cost occurs, which does not necessarily result in better knowledge creation and sharing processes than those achieved without any direct cost or effort in smaller teams. However, it is important to note that predicting the optimal team size is a very difficult and uncertain activity, depending heavily on the complexity of team task and previous relationships among individual members.

A tension of equal importance refers to the diversity that we are aiming to establish during team composition. In NPD teams, members of different functional, educational, or cultural backgrounds are usually brought together to accomplish complex and highly uncertain tasks. This heterogeneous composition is almost a prerequisite, given that product development necessitates the utilization of a diversified pool of knowledge and resources so as to maximize creativity and entrepreneurial thinking. However, this diversity does not come without a price. Greater diversity may result in an increase in product development lead time, caused by coordination problems or different priorities and goals among team members. Similarly to group size, determining the optimal degree of diversity is a complex exercise that is influenced by the nature of the task and the level of novelty that this task brings to a company.

Concerning group process conditions, the social capital and communication practices occurring within as well as outside team boundaries are of central importance. The quality or social relationships between team members (i.e., frequency and emotional attachment) facilitates a spirit of goodwill that mobilizes collective action toward the accomplishment of common goals. The finding examples discussed support this assertion in the context of interorganizational NPD teams. Specifically, the establishment of benevolence-based relationships was found to promote team performance, decision-making processes, and the alignment of members to team objectives and management structures. Moreover, boundary-spanning activities (e.g., integrated cross-organizational problem solving) acted as means of enlarging team resource base, providing opportunities for stimulating creativity and tapping into the innovation potential of external parties through knowledge-intensive social interactions.

Another process condition recognized in the present work relates to the learning processes carried out by team members to adapt or create new knowledge. In our NPD cases, we identified practices that engender team learning activities, including job rotation, knowledge storage and retrieval procedures, and information scanning across diversified technological fields. Under such conditions, group members are able to learn how to communicate and listen to each other, adapt to changing circumstances, and leverage on the richness of knowledge that every individual brings into the team. In this respect, learning generates a system of collective knowledge that reduces errors and delays, and increases the quality of non-routine group tasks such as NPD (Wong 2004, 2008).

Closely related to intragroup conditions is the establishment of clear and commonly shared strategic goals. Research (e.g., Locke and Latham 2000; Katzenbach and Smith 1993) indicates that clear goals foster a sense of a joint purpose, provide the basis for constructive conflict within the team, and motivate members to perform at their best, thus promoting team effectiveness. Our qualitative evidence was in line with these arguments, underlying the importance of a clear mission and shared goals among partners of NPD interorganizational teams. These factors enabled members to align their activities toward the success of the NPD project through, for example, bridging the gap between R&D and marketing functions, or involving potential end-users to the NPD process.

Finally, the organizational context within which NPD teams operate can also exert influences on their functioning and performance. An enabling organizational environment refers to team support in terms of sufficient resources, training, rewards, and a climate that favors teamwork and innovation (Anderson et al. 2004). The importance of such factors was recognized in one of the most successful cases in our field observations. In particular, the innovation project team under study received the necessary R&D resources, which were generated in-house. This internal R&D focus was actually a strategic choice that allowed the company to build core competencies in related technological areas, hence reducing the innovation development time and securing novel R&D characteristics from being imitated by the competition. In this respect, the collaborative project team took advantage of an internal broad portfolio of technological resources, built on the company's experience of specific market segments, and performed effectively within an organizational culture geared toward experimentation and novelty.

In conclusion, the present work demonstrates the value of teamwork design, process, behavioral, and structural conditions for understanding the performance of teams engaged in cooperative NPD. Confronting effectively size and diversity tensions, establishing an internal team context of benevolence-based relations that facilitates learning and new knowledge creation, and operating within an organizational context that supports teamwork and innovation constitute critical conditions for the success of NPD teams.

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Chapter 3
Knowledge Flows in an NPD Team from the Semiconductor Industry

Dimitris G. Assimakopoulos and Bernard Chapelet

3.1 Introduction

Until recently, multinational high-tech companies with large R&D facilities and budgets thought that they could produce all necessary ideas and knowledge for innovation internally within their R&D departments and related business units. Since the last decade or so, however, even the largest high-tech companies, such as IBM and Intel, have promoted "open," rather than "closed," innovation strategies and business models (Chesbrough 2003; Chesbrough and Crowther 2006), where they systematically profit from knowledge, ideas, and intellectual property that people and organizations outside a particular company produce with respect to new products and services. Companies, such as Nokia, have managed to assemble an integrated "innovation chain" that is truly global. They have been able to implement a collaborative process for innovating that transcends local clusters and national boundaries, becoming what Doz et al. (2001) called "meta-national innovators."

Like earlier research in new product development (NPD) processes across several business units in Hewlett Packard (see, for example, Hansen (1999)), meta-national innovation requires three steps: prospecting (finding relevant pockets of knowledge from around the world), assessing (deciding on the optimal "footprint" for a particular innovation) and mobilizing/transferring (using cost-effective mechanisms to move distant knowledge, often of a tacit nature, without degrading it). When done properly, meta-national innovation, open or closed, can provide companies with a powerful new source of time-based competitive advantage: higher-value "distributed" and "networked" innovation for working together with lead customers (von Hippel 2005) and other strategic partners across geographical and institutional

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boundaries leveraging knowledge-intensive relations and competencies in the point of execution.

This chapter aims to contribute in this body of “meta-national and networked innovation” literature by investigating in depth at the interpersonal level of analysis an NPD team in the AMS business unit of a large semiconductor company in France, and several additional sites in Europe and beyond. The questions we ask through this case study deal head on with the application of computerized social network analysis for collecting, analysing, and visualizing network data related to knowledge-intensive informal interpersonal relations fuelling NPD processes in a cross-functional and multisite team. More specifically, we investigate three knowledge-intensive relations: seeking technical and organizational/managerial advice; discussing new ideas/innovation; as well as discussing the internal and external formal and informal structures underlying the NPD process in terms of meta-national innovation within a large semiconductor firm in France and four additional sites in Italy, Czech, Finland, and India. The results highlight key roles, such as central connectors and knowledge brokers (Cross and Prusak 2002; Cross et al. 2006), that team members play in such an NPD team, and identify key individuals in our case study. Moreover, based on in-depth semi-structured interviews with these key individuals we put forward a set of organizational capabilities for strengthening similar NPD teams in the semiconductor industry.

The paper is divided into five additional sections. Section 3.2 discusses the main concepts and underlying theoretical perspectives related to networked and meta-national innovation in high-velocity markets, such as semiconductors. Section 3.3 presents the research design and methodology, including issues of data collection, analysis, and visualization. Sections 3.4 and 3.5 discuss respectively the empirical findings, based on the application of social network analysis in studying overall network connectivity, as well as identifying key individuals; and, for in-depth interviews with these key members of the NPD team, identifying organizational capabilities fostering NPD. Finally, Sect. 3.6 draws the main conclusions and teases out the implications for theory and practice with respect to strengthening cross-functional and multisite NPD teams.

3.2 Main Concepts

The academic literature has initially adopted a linear view of NPD, starting from marketing or/and R&D departments of large multinational companies (MNCs), and shifted its focus in the last decade or so, to nonlinear “network” models of NPD emphasizing learning and innovation across the value chain, also including key business partners such as lead customers and suppliers (Kleinschmidt et al. 2007; Cooper et al. 2004). A conceptualization of NPD emphasizing the iterative nature of learning among NPD teams, tools, and organizational context is shown in Fig. 3.1. This model links people, systems, and technology for designing and launching a new product (or service) in its organizational context (see Fig. 3.1).

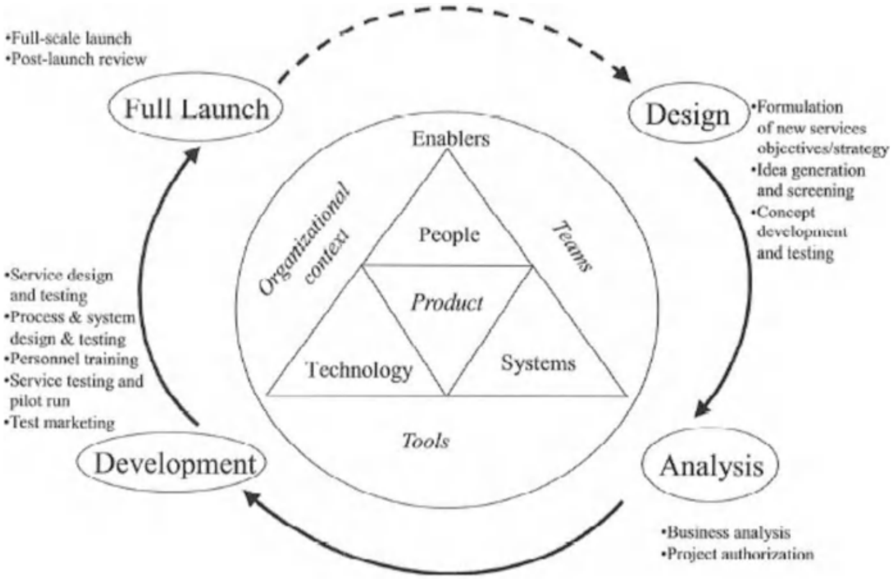


Fig. 3.1 The NPD process

There are strong links between such a view of a NPD process and inimitable resources, such as knowledge-intensive relations, that are located and stem from technological communities (van Maanen and Barley 1984; Rosenkopf and Tushman 1998; Assimakopoulos 2007) and their associated traditions of practice within and across organizational boundaries. Technological communities form the sources and social locus of ongoing technological practice fostering learning and innovation related to new and existing products and technologies, for example, with respect to new AMS chip design. Figure 3.2 shows the main knowledge and socio-cultural dimensions of the concept of technological community and its source concept of technological tradition of practice (Assimakopoulos 2007, 27). In a sense, a cross-functional project team constitutes a formal work-group that comes together for a limited period of time for carrying out a specific job, e.g., the design of a new multimedia platform for mobile handsets. On the other hand, individual members of project teams belong to different technological communities and traditions of practice, for example, with respect to analog or digital design, validation, testing, etc. related to the life cycle of specific design technologies of AMS integrated circuits.

The concepts of community of practice (CoP) and network of practice (Brown and Duguid 2001) are also very useful for our research. As they can respectively help us understand, on the one hand the internal situated nature of learning and knowledge production, enabling innovation within organizations. Lave and Wenger (1991, 98) defined a community of practice as “a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping

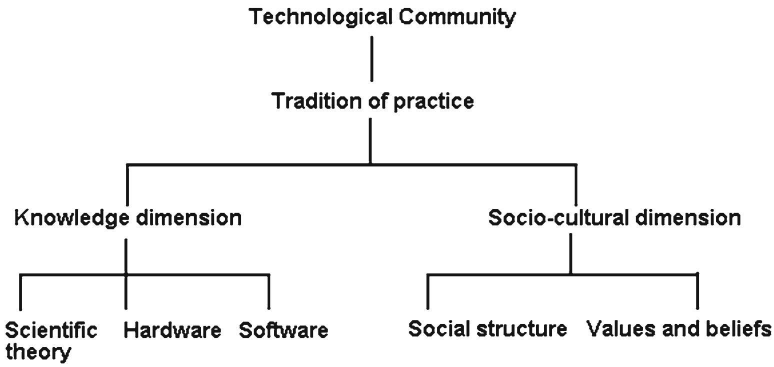


Fig. 3.2 Technological community and basic elements of its source concept of technological tradition of practice

communities of practice." The emphasis here is on interactive learning and knowledge generating and exchange relations through mutual engagement, joint enterprise, and shared repertoire within an organizational setting (Wenger 1998). On the other hand, networks of practice that can help us understand how practitioners learn following the rails of common practice across organizational boundaries, say from colleagues who are often located in the regional innovation system (Autio 1998; Brown and Duguid 2002), or/and across large geographical distances from the global R&D network of their company, performing what Doz et al. (2001) coined as metanational innovation. According to Santos et al. (2004, p.31), many MNCs have supply chains that are global, but few of them have innovation processes, including NPD, that are equally global by sourcing and integrating knowledge from dispersed geographical locations.

Reflecting on the broader trend of increasing new forms of organization for innovation and competition a decade ago, Dyer and Singh (1998, 660) put forward a "relational view" of strategy and competitive advantage, arguing that "the (dis) advantages of an individual firm are often linked to the (dis)advantages of the network of relationships in which the firm is embedded." This relational view of how firms create, sustain (or, lose) competitive advantage with respect to NPD, reflects a "third way" for conceptualizing strategy in the 2000s, on top of the "industry structure view," mainly associated with Michael Porter in the 1980s, and the "resource-based view" put forward by Penrose and developed in the last decades by scholars, such as Teece (1987), Barney (1991), and Spender (1996).

From the outset, the "relational view" of competitive advantage shifts the emphasis of the discussion from individual firms as the unit of analysis to the interorganizational and interpersonal networks that a firm's critical resources and capabilities may stem from and depend on. Moreover, the "relational view" builds on the "resource-based view" of the firm, with respect to the importance of knowledge underlying inimitable resources and dynamic capabilities, such as NPD and decisions regarding strategic alliances (e.g., Kogut and Zander 1996). Recent insights from business strategy (e.g., Eisenhardt and Martin 2000) have pointed out the

Table 3.1 Dynamic capabilities in moderately dynamic and high velocity markets (source; Eisenhardt and Martin 2000: 1115)

	Moderately dynamic markets	High-velocity markets
Market definition	Stable industry structure, defined boundaries, clear business models, identifiable players, linear and predictable change	Ambiguous industry structure, blurred boundaries, fluid business models, ambiguous and shifting players, nonlinear and unpredictable change
Pattern	Detailed, analytic routines that rely extensively on existing knowledge	Simple, experiential routines that rely on newly created knowledge specific to the situation
Execution	Linear	Iterative
Stable	Yes	No
Outcomes	Predictable	Unpredictable
Key to effective evolution	Frequent, nearby variation	Carefully managed selection

significance of dynamic capabilities in high-velocity markets, such as semiconductors, where the resource-based view's emphasis on long-term advantage is often problematic, and short-term, unpredictable advantage is the norm. Table 3.1 shows that in high-velocity markets dynamic capabilities, such as product development and strategic decision-making with respect to networking and collaboration, are simple, highly experiential, and fragile processes with often unpredictable outcomes. Ambiguous industry structure, porous boundaries, and fluid business models are only some of the contrasting differences of dynamic capabilities in high-velocity markets compared to the ones in moderately dynamic markets (e.g., automotive) that are more detailed, relatively structured analytic routines (Feldman 2000) that rely extensively on existing knowledge and stable processes with predictable outcomes (see, Table 3.1).

A "relational view" of strategy and the distributed nature of technological and dynamic capabilities necessary for learning and innovation in high-velocity markets shift the emphasis of the discussion from individual firms to the architecture of collaboration in dyads, triads and networks of collaborating and competing organizations, individuals and their technological communities, and communities of practice. A "relational view" is missing from the CoP theory of learning and innovation in organizations, where recent research highlighted that CoPs seem to be rather inward looking, group-centric, and bounded within organizational boundaries (Swan et al. 2002; Doak and Assimakopoulos 2007). Since CoP theory conceptualizes organizations as a constellation of CoPs, it overlooks much of the ongoing discussion on the strategic significance of new forms of organizations for learning, innovation, and the acquisition of technological capabilities distributed among a network of collaborating and competing firms, and other knowledge-generating organizations, such as universities (Carayannis and Alexander 1999; Etzkowitz 2003). This shortcoming of CoP theory with regard to how information and knowledge flows across the firm boundaries has recently been highlighted by Brown and Duguid (2001) in their discussion of networks of practice, or how knowledge flows across the rails of common practice, for example, among private and public organizations in Silicon Valley (Brown and Duguid 2000, 2002).

According to Assimakopoulos (2007), in fast-moving fields, such as semiconductors, social networks of a personal nature matter for shortening new product cycles and yielding a comparative advantage for networked and distributed innovation business models. Moreover, knowledge-intensive relations binding practitioners in their technological communities and traditions of practice are informal in nature and complement the formal nature of project teams put together for achieving specific organizational objectives, such as NPD. The analysis of social networks at the interpersonal level (Cross and Parker 2004, and, Cross et al. 2006) is therefore a powerful tool to map informal networks among project team members in time critical points of their NPD efforts, for examining whether they bring in (or not) critical knowledge and ideas for innovation. In addition, social network analysis has the power to uncover the distinctive competencies related to the degree of alignment of formal organizational structures, such as NPD project teams, with informal structures, such as networks of practice (Brown and Duguid 2001), and key individual roles (Cross and Prusak 2002) for networked innovation, such as "knowledge brokers" and "central connectors." In addition to studying patterns of informal, tacit knowledge exchange, embedded in collaboration networks, as seeking technical advice from the local community of practice, or personal networks connecting project team members with external people from the global R&D network of the firm, performing meta-national innovation.

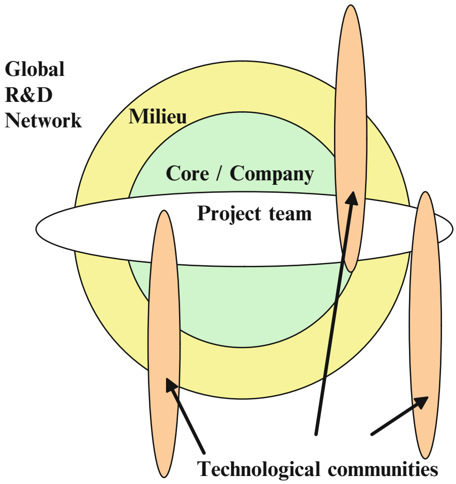
Moreover, there is very little known from the academic literature about the relation between "systemic" innovation at the regional and multinational levels of analysis, though a plethora of studies have focused on interorganizational networks between MNCs and their key business partners for product innovation, interactive learning, and economic performance (Christensen and Lundvall 2004). Recently, prominent regional economist Annalee Saxenian (2006) has introduced the notion of "New Argonauts" to describe how mainly Indian, Chinese, and Israeli engineers and entrepreneurs have maintained one foot in Silicon Valley and the other in places as far apart as Hsinchu in Taiwan, Bangalore in India, and Tel Aviv in Israel, building global innovation, research and production networks over large geographical distances and contributing to the strengthening of the economies of global technology regions in the most dynamic parts of the world. There are clearly similarities between the New Argonauts and the roles (e.g., knowledge brokers) individuals play in social networks. It is worth therefore investigating in more depth what are the competencies that individuals playing these roles bring into the innovation and NPD processes. Do New Argonauts or bridges exist in projects like the one we studied? What are the links of such individuals with their respective technological communities and traditions of practice? The interrelations between individual and organizational capabilities at the business unit level seem of paramount importance for fostering NPD teams in critical areas for a competitive future. We therefore selected an NPD team within the AMS business unit of a semiconductor MNC as the unit of analysis for our investigation.

3.3 Research Methodology

An NPD project team generally brings together a set of managerial/organisational and technical capabilities and relations (Rizova 2006, 2004) gathered for the development of a new product within an agreed timetable. An example is the cross-functional project team, which was selected for our AMS case study in Spring 2007. This NPD team brings together about 60 people (analog and digital designers, architects and back-end designers, validation engineers, testers, marketing and sales people, etc.) from Grenoble in France and four additional sites: Milan in Italy, Prague in Czech, Helsinki in Finland, and Noida in India, for developing a new multimedia AMS chip for a leadcustomer, over a 3-year period, from mid-2005 to mid-2008. This AMS project team draws on the knowledge and socio-technical resources of technological communities which are both local/global, i.e., "glocal," and internal/external to the company, embedded to a certain extent in regional innovation systems (clusters) for enabling interactive learning and knowledge generation and exchange for carrying out its tasks with respect to NPD. Figure 3.3 shows the main elements and concepts involved in the NPD process.

Since our unit of analysis is the project team, we argue that knowledge, mainly of a tacit and relational nature, as the main resource for NPD can be drawn to a project team from a broad range of geographical scales at multiple organizational levels:

- From the core of the project team at Grenoble with respect to the analog design technological community.



Core: Local teams of new product development (NPD) internal to the company.

Milieu: NPD teams external to the company but within the cluster / regional innovation system.

Global: Global teams of NPD internal or external to the firm but related to the company's global R&D network.

Fig. 3.3 Main elements/concepts in NPD – project team and technological communities at a multiscalar environment

- From additional technological communities related to the global R&D network of the company, (e.g., from Prague with respect to validation and testing; from Noida with respect to the USB interface, etc.).
- From the local cluster/regional innovation system including public research institutes, universities, etc. (e.g., from the National Polytechnic Institute of Grenoble).
- From key business partners such as lead customers that have participated heavily in the new product proposal and specification stages helping to codesign the new chip and associated platform for their next-generation mobile phones.

Moreover, we assume advice-seeking relations to be the context where through social interactions inimitable tacit knowledge is created and shared, fuelling the NPD process of the project. Advice-seeking relations focusing on organizational and/or technical issues, as well as new ideas/innovation among engineers, analog and digital designers, etc. form a multistranded social network. This social network, though invisible, is of critical importance for understanding the knowledge-sharing process in such a distributed and multi-functional NPD. Inter-personal networks also bridge the micro- and macrolevels of analysis, as well as large geographical distances associated with meta-national innovation and about a dozen technological communities linked with the design of such a complex new product. The application of SNA, therefore, is particularly useful for analysing and visualizing the knowledge-sharing process and highlighting the role of specific individuals, technological communities as well as geographical locations/sites.

The six steps of our research methodology included:

1. Select an appropriate project team for NPD in the AMS business unit.
2. Get the list of names of team members, e-mails, countries, technological communities, etc. for the project applying the SNA methodology – a survey questionnaire has been developed, in consultation with the participating business unit.
3. Upload the SNA survey questionnaire at the dedicated Network Roundtable platform of the University of Virginia, https://webapp.comm.virginia.edu/networkroundtable/ for enabling web-based data collection, including possibility for creating individual action plans for all survey respondents.
4. Send out invitations to all project team members and start collecting network data with the support of the sponsoring business unit – a 70% response rate was achieved by July 2007, after follow-up with two reminder e-mails to the nonrespondents in May and June 2007. Particular attention was given to ensure the responses of all key individuals in the team.
5. Analyse and visualize three bounded social networks of informal knowledge-intensive relationships within the selected project team, plus personal networks nominating external sources of information/knowledge from the “glocal” R&D network of the company, the regional clusters, and key business partners, including lead customer and main suppliers; compute metrics at the network (density, distance) and node (in-degree and flow betweenness centrality) levels of analysis (Wasserman and Faust 1994), identifying key individual roles, such as knowledge

brokers and central connectors (Cross and Prusak 2002), by deploying the UCINET (Borgatti et al. 2002) and NETDRAW (Borgatti 2002) SNA and visualization software.

6. Go back after the identification of key roles and people to interview in-depth these key members, i.e., knowledge brokers and central connectors, of the project team for showing the results and collecting additional qualitative and quantitative feedback from these key respondents, for fostering organizational capabilities for NPD in AMS.

3.4 Main SNA Findings

The main findings from our NPD project team are presented below with respect to both internal and external knowledge-intensive linkages connecting more than a 100 people coming from a dozen technological communities and based in half a dozen countries. In terms of the internal linkages shedding light to the ongoing workings of the NPD team, we studied three sets of relationships:

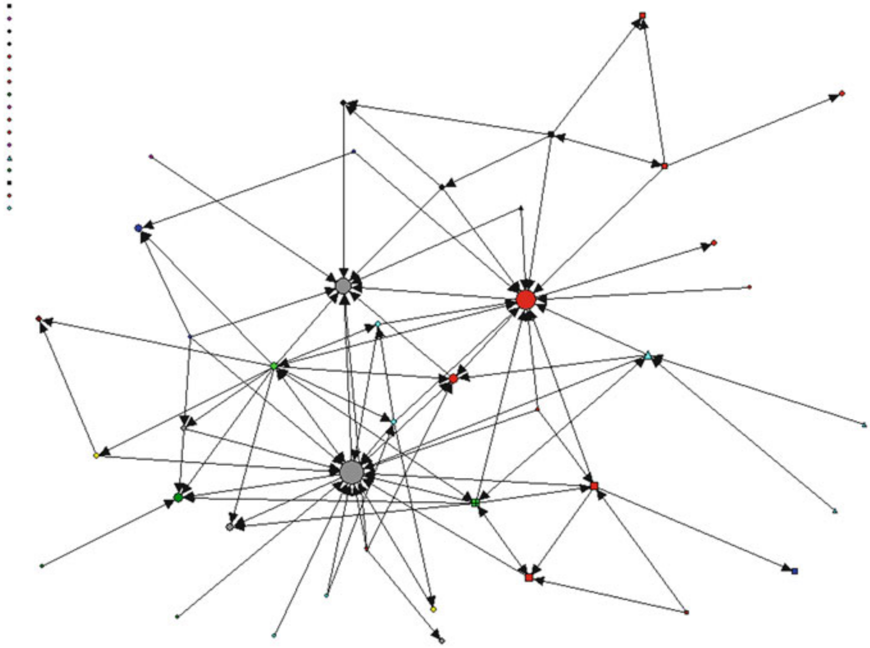
- Seeking managerial/organizational advice (see Sect.) 3.4.1
- Seeking technical advice, (see Sect.) 3.4.2
- Discussing new ideas/innovation, (see Sect.) 3.4.3

As a result of the network analysis and visualization we have studied overall network connectivity for NPD and identified the key people and roles for this AMS team (see Sect. 3.4.4). In terms of the external linkages connecting the members of the project team with the global R&D network of the company, the regional innovation systems/clusters, and business partners such as customers and suppliers, see Sect. 3.4.5.

3.4.1 Seeking Managerial/Organizational Advice

Graph 1 shows the bounded network of seeking managerial/organizational advice in the NPD project team based on a 70% response rate (40 out of 58 respondents). Note that we switched off the labels in Graph 1 for protecting the anonymity of our respondents. From the outset, Graph 1 shows all 58 individual team members/nodes classified according to the following attributes:

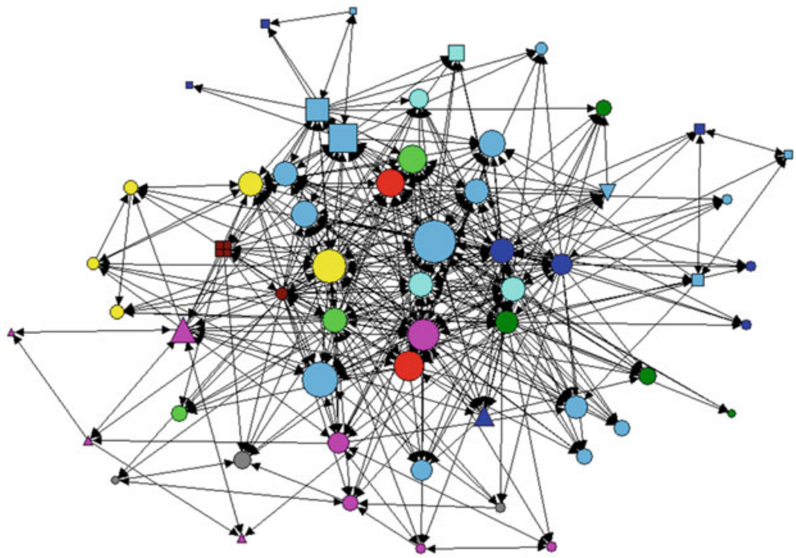
- Size of node – based on individual score of in-degree centrality (i.e., how many others turn to this individual for seeking advice with respect to managerial and organizational issues)
- Color of node – based on a classification of technological communities (■ analog designers, ■ digital designers, ■ back-end designers, ■ architect designers, etc.)



Graph 1 Seeking managerial/organizational advice

- Shape of node – based on a classification of countries (circles in France, boxes in Italy, triangles in Czech, reverse triangle in India, crossed box in Finland)

The linkages are directional reflecting who is seeking advice from whom in Graph 1. Note that there are 17 isolates, individuals who do not go to anybody else in the team for seeking advice with respect to managerial and organizational issues related to the project, as a result of mainly employee empowerment policies and horizontal relations among team members. Obviously, few individual members, such as the project managers, receive many more requests for advice and therefore score higher in-degree centrality scores compared to others. The positioning of the nodes in the Graph 1 is computed based on a measure of structural equivalence, i.e., Euclidian distance (Burt 1987). The visualization is based on a spring-embedding algorithm of NETDRAW (Borgatti 2002). The underlying assumption here is that the distance between any two nodes reflects the structural similarity of these nodes. If two nodes have similar patterns of connections to all other nodes in this network, then their distance should be small. If two nodes have identical patterns of connections, then the Euclidian distance between them is zero and the nodes should be placed on top of each other on a two-dimensional graph, like Graph 1.

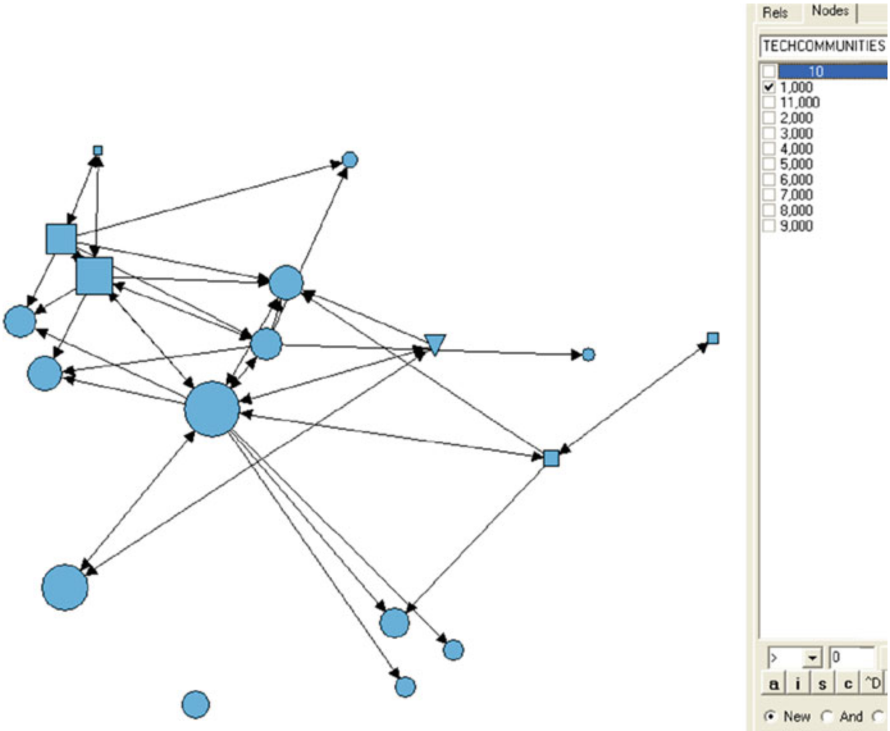


Graph 2 Seeking technical advice

3.4.2 *Seeking Technical Advice*

Graph 2 shows the bounded network of seeking technical advice in the AMS project team. It is based, like Graph 1 on a 70% response rate (40 out of 58 respondents) and once more we switched off the labels in Graph 2. Note that there are no isolates in Graph 2. As a result, Graph 2 shows many more advice-seeking linkages compared to Graph 1, and many more nodes receive several requests for technical advice and therefore score a considerable in-degree centrality. The assumptions underlying Graph 2 are the same like in Graph 1 with respect to the visualization of linkages and the positioning of the nodes based on Euclidian distances as a measure of structural equivalence. Like above, Graph 2 shows all 58 individual team members/nodes classified according to the following attributes:

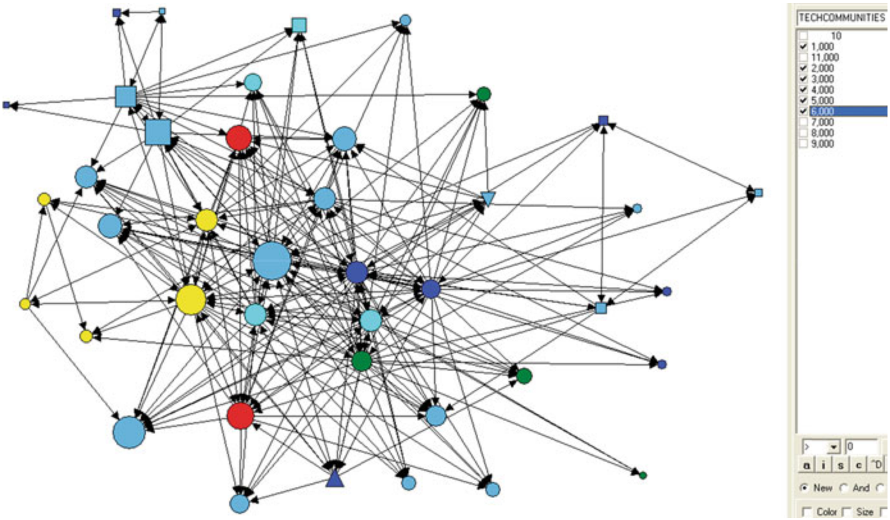
- Size of node – based on individual score of in-degree centrality (i.e., how many others turn to this individual for seeking advice with respect to technical issues)
- Color of node – based on a classification of technological communities (■ analog designers, ■ digital designers, ■ back-end designers, ■ architect designers, ■ other designers, ■ application, ■ marketing and sales, ■ test/production/validation, ■ quality/reliability, ■ planning, and ■ managers)
- Shape of node – based on a classification of countries (circles in France, boxes in Italy, triangles in Czech, reverse triangle in India, crossed box in Finland).



Graph 2.1 Seeking technical advice within the analog designers technological community – size of nodes shows in-degree centrality and shapes show country

Graph 2.1 is a subgraph derived from Graph 3.5 showing the pattern of interpersonal relations seeking technical advice within the technological community of analog designers. The different shapes indicate the geographical locations of team members, i.e., circles in France, boxes in Italy, and reverse triangle in India. The pattern of linkages shows, unsurprisingly, that the members who are the most central in this technical advice network are located in France. These individuals are also well connected with few of their colleagues in Italy where there is particular expertise in design for analog audio signal and the positioning of these nodes is near to each other in the Graph 2.1, as a result of their patterns of connections which are similar to each other, i.e., their Euclidian distances are relatively small. The only Indian analog designer in the Graph is connected directly only with one French analog designer, the second most central node in the Graph 2.1.

Graph 2.2 shows seeking technical advice relations within all designer and application technological communities. As it can be seen from Graph 2.2, a few analog designers in France and Italy are the most central of all designers, followed by the application expert and a couple of architect designers in Grenoble. As this NPD project is part of a very complex new chipset and platform for a third-generation mobile handset, it is expected to handle both audio-analog signal and digital data

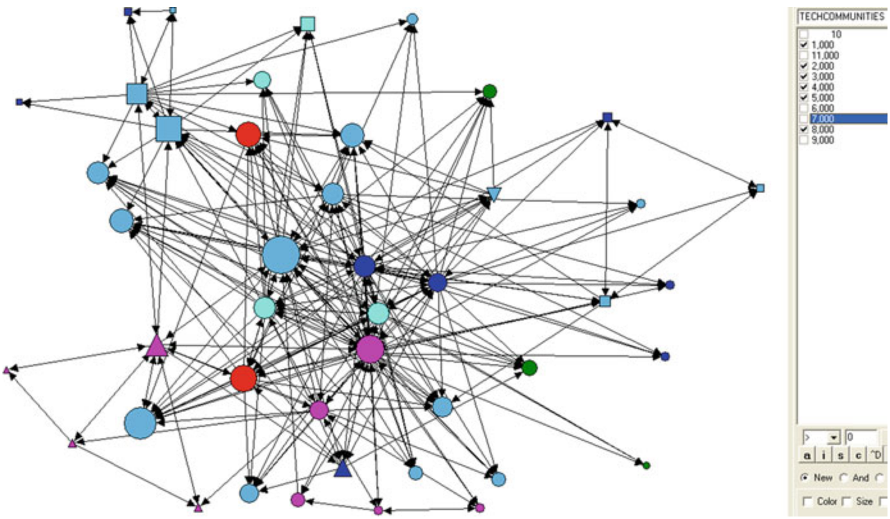


Graph 2.2 Seeking technical advice relations within all designer and application technological communities (analog designers, digital designers, back end designers, architect designers, other designers, CAD, etc., application)

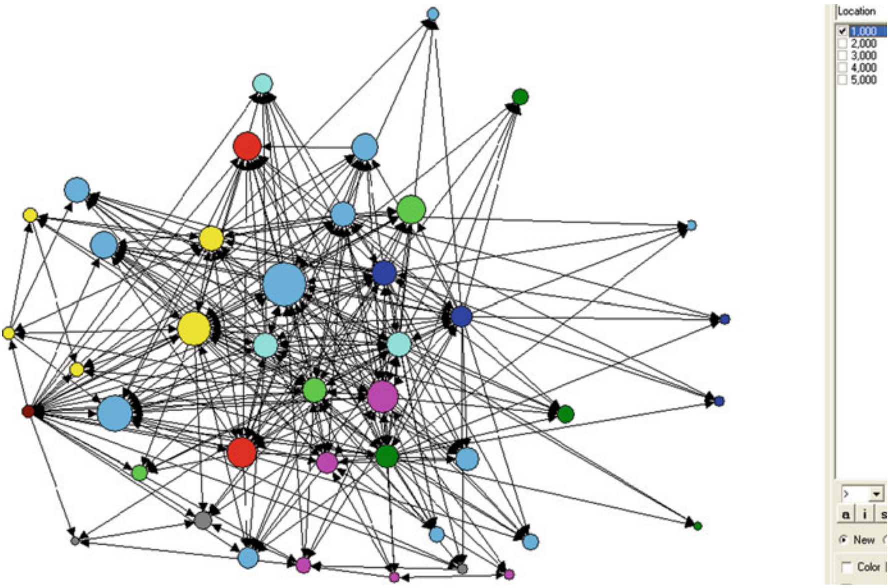
and applications, such as e-mail, web browsing, digital photos, and videos. It is therefore reasonable that applications experts play such an important role alongside analog designers and architects. The same applies for the test, production, and validation engineers in Grenoble and Prague (triangle, see Graph 2.3), who work very closely together in this NPD team and seek technical advice from the analog and architect designers in Graph 2.3, plus a few of the digital and back-end designers.

Last but not least, in terms of the geography of linkages, Graph 2.4 and 2.5 show the patterns of technical advice-seeking networks in and outside France, in the four additional sites of the NPD team, in Italy, the Czech Republic, Finland, and India. Both Graphs provide evidence for the nature of meta-national innovation and the social and knowledge networks underlying the collective competencies and organizational capabilities for learning and integration fuelling this NPD team (Ettlie and Pavlou 2006). In particular, Graph 2.4 shows all the designers, plus all other team members, coming from a broad range of technological communities and CoPs, such as application, test/production and validation, marketing and sales, planning, quality and reliability experts, and, last but not least, project managers, who are all based in France – most of them are located in Grenoble.

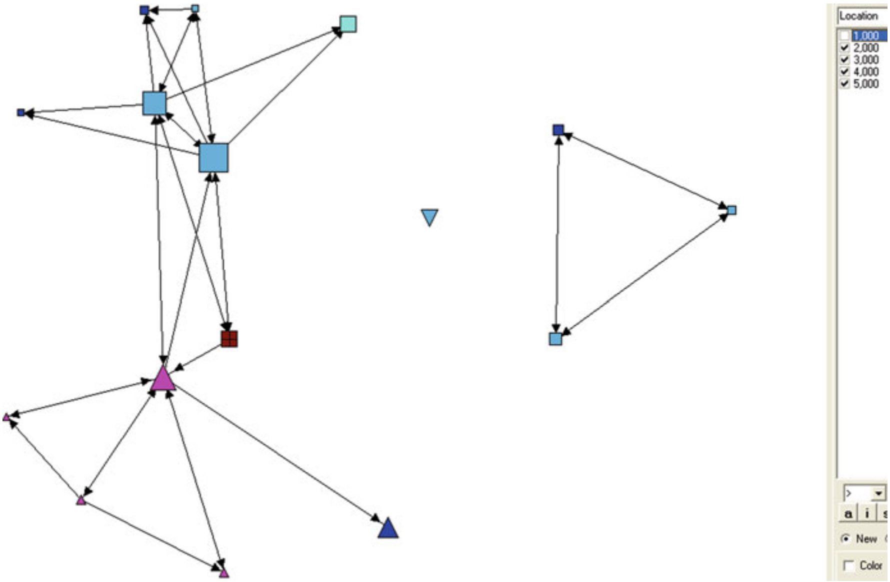
Moreover, Graph 2.5 shows that both the analog designers based near Milan, and the production/test/validation engineers in Prague maintain their respective cohesive subgroups based on their common background with a number of overlapping cliques in Italy and the Czech Republic. While in both subgroups there are one or two individual members who directly provide connectivity across these subgroups and with the sales and marketing expert in Helsinki, who connects this NPD team with its lead customer.



Graph 2.3 Seeking technical advice within all designer and test/production/validation technological communities (■ analog designers, ■ digital designers, ■ back end designers, ■ architect designers, ✸ other designers, CAD, etc., ✸ test/production/validation)



Graph 2.4 Seeking technical advice among the members based in France (*circles*)



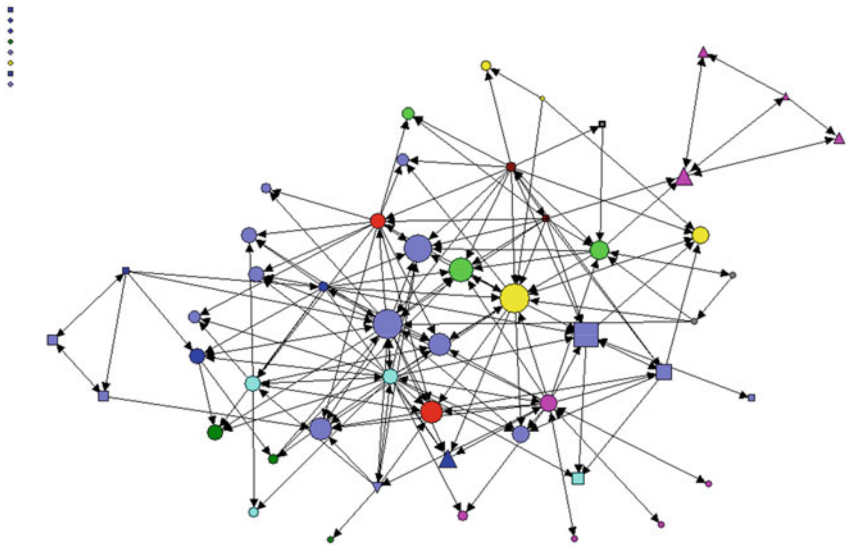
Graph 2.5 Seeking technical advice among the members of the Touareg2 team based outside France (*boxes* in Italy, *triangles* in Czech, *reverse triangle* in India, *crossed box* in Finland)

3.4.3 Discussing New Ideas/Innovation

Graph 3 shows the bounded network of discussing new ideas/innovation in the AMS project NPD team. It is based, like the Graph. 1 and 2, on a 70% response rate (40 out of 58 respondents). Note that there are eight isolates in Graph 3. As a result, Graph 3 shows many more new ideas seeking linkages compared to seeking managerial advice linkages in Graph 1, and much fewer technical advice seeking linkages in Graph 2. These observations are quantified in the next subsection through the computation of densities and average distances connecting all people in Graph 1–3. The assumptions underlying Graph 3 are the same like above with respect to the visualization of linkages and the positioning of the nodes based on Euclidian distances as a measure of structural equivalence.

Graph 3 shows all 58 individual team members/nodes classified according to the following attributes:

- Size of node – based on individual score of in-degree centrality (i.e., how many others turn to this individual for discussing new ideas/innovation)
- Color of node – based on a classification of technological communities (■ analog designers, ■ digital designers, ■ back-end designers, ■ architect designers, ■ other designers, ■ application, ■ marketing and sales, ■ test/production/validation, ■ quality/reliability, ■ planning, ■ and managers)

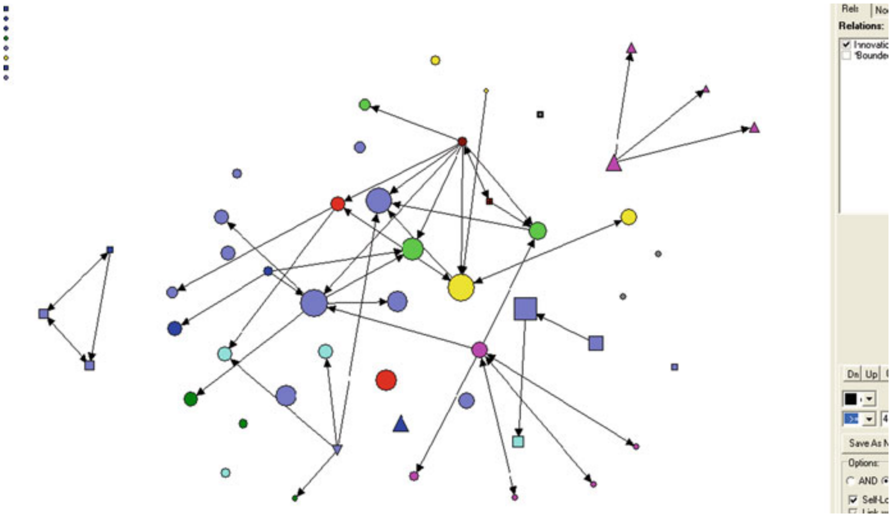


Graph 3 Discussing new ideas/innovation

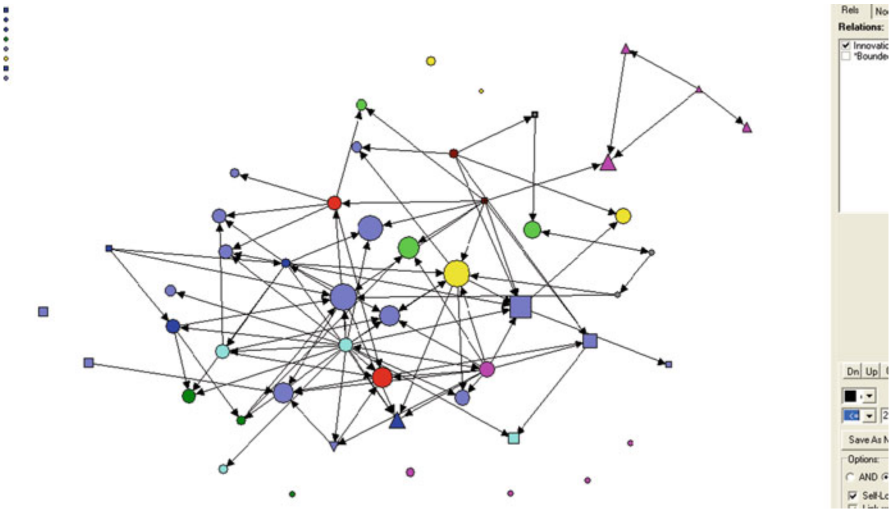
- Shape of node – based on a classification of countries/geographical location (circles in France, boxes in Italy, triangles in Czech, reverse triangle in India, crossed box in Finland).

Graph 3.1 and 3.2 are derived from Graph 3 and focus on the notions of strong and weak ties (Granovetter 1982), based on frequency of interactions among members of this NPD team, as well as the significance of key attributes of technological communities and geographical location/countries illustrated in Graph 3. Weak ties connect individuals when they discuss innovation and new ideas once every month or once every 3 months. On the other hand, strong ties connect individuals, when they discuss new ideas and innovation once every week, or twice, or more every week. From the outset, it seems reasonable that there are many more weak ties compared to the strong ones, as the majority of the AMS team members prefer to discuss new ideas once a month, or less often.

Graph 3.1 shows that the majority of strong ties connecting people of the same technological community (color) and country (shape). For example, analog designers in Italy, or test and validation engineers in Prague, or Grenoble, do tend to discuss very often with each other about innovation. Only few strong ties cross technological communities, for example, in the case of test and validation engineers in Grenoble, who talk very often about new ideas with the most central analog designer, and one of the project managers in Grenoble. It is worth noting, however,



Graph 3.1 Discussing new ideas/innovation – strong ties



Graph 3.2 Discussing new ideas/innovation – weak ties

Table 3.2 Densities and distances of the Graph 1–3 above

	Graph 1	Graph 2	Graph 3.1
Density	8.2%	41.5%	13.7%
Distance	2.97	2.08	3.34

that the marketing and sales people in Grenoble maintain a number of strong ties not only with the project managers in Grenoble and lead customer in Helsinki, but also with the most central analog designers and application experts. The same applies to the Indian analog designer who maintains strong links across with the analog and digital designers in Grenoble.

Graph 3.2 shows the weak ties in the AMS team. As it can be seen in the Graph 3.2, there is a huge main component connecting most of the people in this innovation network showing that people from different technological communities and countries do discuss at least once every month, or every 3 months, about new ideas in relation to their NPD efforts. In particular, there seem to be few key knowledge brokers (Cross and Prusak 2002) who come from each site and transcend disciplinary boundaries connecting with weak ties the different technological communities and locations of the team.

3.4.4 Quantifying Overall Network Connectivity and Identifying Key Individual Roles

Graph 1–3 above have visually dissected three internal networks underlying the NPD process of the AMS project team in Spring 2007. We also put forward a series of subgraphs for providing indepth insights into NPD through illustrations of how people from a broad range of technological communities and countries connect in practice to each other with regard to three knowledge-intensive relations for NPD. Table 3.2 shows the densities and average distances connecting any two nodes/people in the Graph 1–3. Note that the density of a graph shows the percentage of real ties against the maximum possible, i.e., a graph that all people are connected with all others. Distance shows average distance (how many steps is the shortest path) for people to get to all other people in the network.

We assume that a graph with density below 25% and distance greater than 2.5 steps shows a social network that it has low density and does not facilitate fast and accurate communication among its actors. Distances of two steps or below show a network with relatively short distances, and shorter distances mean faster, more accurate sharing of information and leveraging of tacit knowledge for NPD (Leonard and Sensiper 1998). As it can be seen from Table 3.2, the people belonging in the AMS project team form a dense and well-connected network with respect to seeking and exchanging technical advice for NPD, as the density of Graph 2 is relatively high 41.5% and the average distance connecting any two people is rather short, i.e., about two steps in average. However, for the two other networks of seeking managerial

Table 3.3 Central connectors/local champions

Central connectors/local champions	Indegree/technical advice	Indegree/innovation
YM	28.4	8.4
NB	23.5	9.5
CD	21	10.5
XT	19.3	6.7
YR	17.5	3.5
CP	15.8	6.0
BM	15	6.7
MC	14.4	7.7
MT	13	4.5
TL	11	4.6

advice (Graph 1), and discussing new ideas and innovation (Graph 3), the densities are relatively low and the distances for exchanging information are rather long. It may be therefore worth exploring scenarios for improving the connectivity of the Graph 1, and more importantly Graph 3, in a year or so.

It is also of interest in shifting the analysis from the "forest" of all linkages in the graphs above to individual "trees" for identifying key roles that specific individuals play, such as central connectors and knowledge brokers (Cross and Prusak 2002) for enabling knowledge sharing and flow within a multifunctional and multisite NPD team. This shift implies computing with UCINET (Borgatti et al. 2002), not only network-level metrics, such as density, but also node-level metrics, such as in-degree and flow betweenness centrality (Wasserman and Faust 1994). Degree centrality indicates how popular or well connected each individual is in a network/graph, or how many other people are directly connected with a focal individual making this individual a central (or less central) connector/local champion for the whole network. More importantly, if the linkages are directional like in the Graphs above it is sensible to calculate in-degree centrality, or how many people turn to each individual for seeking, say, advice about technical issues related to the project. Out-degree would merely reflect to how many others a focal individual goes for seeking advice, say with regard to technical issues. As each individual has reported his/her own linkages to all others in the project team, it is a more reliable measure to take into account what all others say for each individual, rather than vice versa. Flow betweenness centrality indicates the extent to which each individual lies along the shortest paths of all other people in a network controlling the flow of information and therefore playing the role of knowledge broker in a network.

Table 3.3 shows the top central connectors and local champions in Graph 2 and 3 with respect to in-degree centrality for seeking technical advice and discussing new ideas/innovation. The individual scores are normalized so that like percentages they can be compared for identifying the top central connectors and local champions across different relationships, i.e., technical advice and innovation. For protecting the confidentiality of these individuals, we only use initials. Likewise, Table 3.4

Table 3.4 Knowledge brokers

Knowledge brokers	No. of external contacts	Betweeness/technical	Betweeness/ innovation
CP	2	7.9	7.4
RK	3	7.7	7.5
NB	3	7.0	0
YM	1	6.1	6.0
MO	4	6.4	7.4
CG	17	6.0	1.7
CD	10	4.8	5.8
PL	14	5.9	5.9
XT	8	4.6	4.6
HN	3	4.3	4.3
CC	9	2.2	1.7

shows the top knowledge brokers in Graph 2 and 3 with respect to flow betweenness for seeking technical advice and discussing new ideas/innovation in the AMS team. Note that Table 3.4 also indicates the number of external linkages, nominated individuals that each of these people has nominated from the global R&D network of the company, regional cluster, and business partners, including suppliers and customers. The names/initials in bold indicate people who have been identified in both Tables 3.3 and 3.4, therefore playing the key individual roles in the AMS project team.

3.4.5 External (Yellow) and Internal (Red and Blue) Nodes and Linkages

In addition to the three sets of internal linkages, we also collected nomination data about the external informal linkages of the project team. Each member was asked to provide all his/her external sources of information important for the AMS project from the global R&D network of the company, the regional clusters, and customers and suppliers. Based on our 40 (out of 58) survey respondents we therefore collected 127 nominations (including names, e-mails, company names, and countries that each external contact is based in). Figure 3.4 shows the AMS project team divided into 16 red core nodes (the key individuals identified above in Tables 3.3 and 3.4), and 42 blue nodes (the remaining project team members), with all their 127 external contacts, yellow nodes. Overall Fig. 3.4 encompasses 185 individuals in Europe, the USA, and India. Note that about two-thirds of the AMS team is based in France.

An important finding is that about 80% of all external contacts are based in France, raising questions about the extent to which the AMS project team has

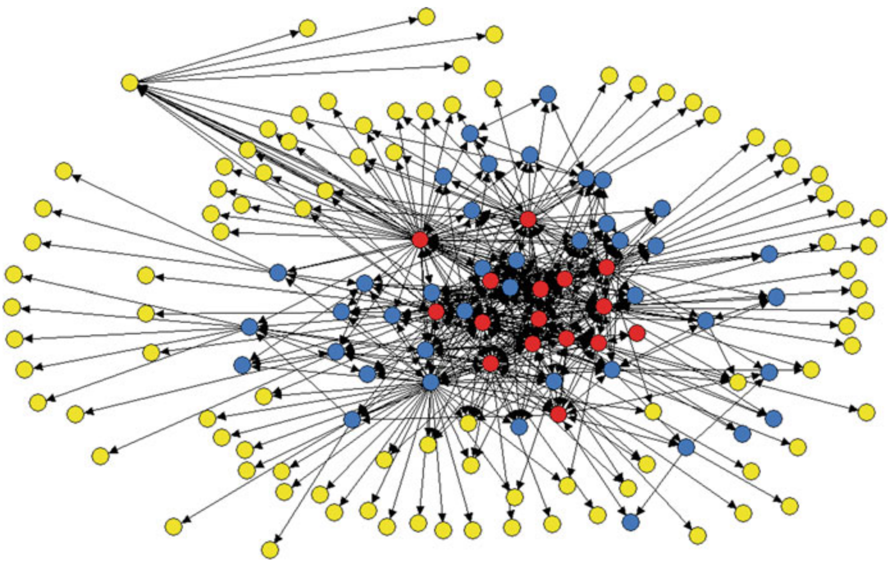


Fig. 3.4 Internal (*blue* and *red*) and external (*yellow*) nodes and linkages

capitalized on the global R&D network of the company, and whether this is a meta-national "open" NPD project where we can find "new argonauts" or "bridges" connecting the Grenoble core with places as far as India and the USA. Only a handful of nominations are based outside the five countries the project team has already members. Surprisingly, there also seem to be very few external linkages of the team with the local clusters, as less than 10% of the nominated external contacts go to the clusters under study. Nonetheless, few of our respondents as a result of their long-standing membership in technological communities, such as sales and marketing, provided as many as 15 or more external contacts each (see also Table 3.4). The majority, however, nominated only a few external contacts each, with the notable case of few highly central individuals playing key roles as central connectors (e.g., CP), and knowledge brokers (e.g., XT).

Figure 3.5 focuses on the core of Fig. 3.4 and shows the 16 key individuals identified above and their external contacts only. It is worth following up these nominations in the future, for uncovering their linkages in a second round of fieldwork, and their nominations in a third one and so on, for applying a snowball sampling in terms of studying where the linkages of the key players go in Europe and beyond. It seems also promising studying these personal networks, in terms of both internal and external ties, for strengthening future individual and organizational capabilities fuelling the NPD process in Grenoble and beyond.

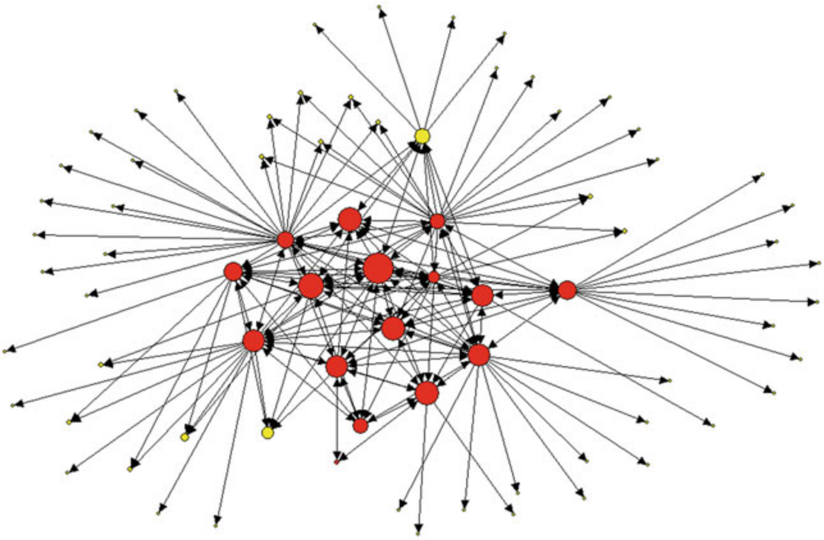


Fig. 3.5 Core internal (*red*) and external (*yellow*) nodes and linkages

3.5 Fostering Organizational Capabilities

Based on the identification of the 16 key people in the AMS team, we also carried out ten in-depth interviews, ranging between 90 and 120 min., with key core team members representing all technological communities and functions in Grenoble. These leading engineers and experts agreed to be interviewed for identifying individual and collective/organizational capabilities for NPD, so that we could spell out recommendations for strengthening local NPDs in the near to medium-term future at their business unit level of analysis. Our findings have also been discussed with the managers of the AMS project and business unit for further validation and generalization. As a result of our research, various recommendations were made for:

- Setting up technical and managerial expert groups to implement actions/policies for strengthening individual and collective competences of "glocal" NPD teams.
- Managing the AMS business unit for implementing tools to be used on a regular basis for the strengthening of NPD teams.

The organizational capabilities to be strengthened were found that they take place against a context of continuous organizational and technological change where the main drivers for change are the following:

- The move towards the supply to the customer of chipsets mostly specified by the semiconductor manufacturer (formerly these were mainly specified by the customer).

- The increased offshoring and outsourcing of IP blocks and tasks to better exploit offshored resources and reduce development costs.
- The request for additional services to potential customers in a situation where the design and development follow the specifications of the semiconductor manufacturer rather than lead customer(s). And overall:
- The need to pinpoint, access, and absorb in a dynamic way the knowledge of the local and global technological communities related to NPD within or outside the company.

At the business unit level, such organizational capabilities have been analysed with regard to an array of four distinctive collective competences:

1. The capability to lead chipset innovation:
   - The capability to anticipate evolution of needs at the final customer level, e.g., handset manufacturer.
   - The capability to understand the associated ecosystems linking NPD teams with lead customers and main suppliers.
2. The capability to manage lead customer(s) pervasiveness and think application(s)
   - The capability to compensate for development risks by being proactive and agile.
3. The capability to manage complex NPD projects in a meta-national mode:
   - The capability to mobilize adequate technical and managerial resources from different sites and countries.
   - The capability to think and act "glocally" for NPD at the business unit level to stimulate the development of new resources in a meta-national innovation mode, through a broad range of organizational arrangements from own "home" NPD development based on the glocal R&D network of the company, contractual links with local R&D laboratories, creation of start-ups through spin-off activities and corporate venturing and, last but not least, acquisition of young entrepreneurial firms.
4. The capability to pinpoint, access, and absorb in a dynamic way the knowledge of the local and global technological communities related to NPD within or outside the company
   - The capability for continuous learning and adding value to the internal knowledge of NPD project teams and competence centers, i.e., technological communities.
   - The capability to exploit and enrich technologies developed by different business units as well as the technologies of partners upstream in the value chain.
   - The capability to absorb external knowledge from local stakeholders, for example, public research laboratories such as the CEA-LETI http://www-leti.cea.fr/ in Grenoble.

3.6 Concluding Thoughts

This case study has highlighted the distributed and network architecture of knowledge for NPD in a leading ongoing project within the AMS business unit of a semiconductor MNC in France. Our focus on three interpersonal and informal networks has identified with the application of socio-metric methods and computerized SNA a small group of leading individuals, who play key roles in a relatively large, 60-people-strong, cross-functional, and multi-site NPD team, distributed in Grenoble and four additional sites in the EU and India. Our network analysis and visualizations (see Graph 1–3 and Tables 3.1–3.3) have also provided insights of both the deep structure of such a team, in terms of key knowledge generating and sharing relations, as well as metrics for studying distributed and networked innovation. In particular, our methodology has the potential to uncover the individuals within (or outside) an NPD team who play critical roles, such as central connectors and knowledge brokers, for fostering meta-national innovation. The latter is of significant importance as more and more NPD teams get international membership, scattered across different countries and continents, for cost or/and knowledge/talent-related reasons.

It is worth noting, however, that in our case the vast majority of key people and knowledge-intensive relations are still located in France. Despite the ever-increasing academic literature in favor of more open and meta-national innovation, there seems to be little evidence in our case to support the value of such organizational and business model for NPD. More than 80% of the nominated people and linkages were found to operate within France. The vast majority of the key sources of information and knowledge were local and operated within each of the five sites and countries who came together for forming this NPD team. Even when participants in our research selected to nominate contacts from the global R&D network of their company, they single-handedly nominated people within their national boundaries, or from local suppliers, or the lead customer, near to their own site. Also, a surprising finding was that there were very few links with the local regional innovation systems and clusters. This finding was further corroborated in our in-depth interviews carried out in Grenoble, when interviewees told us explicitly that they have had very few, if any, contacts with the local research universities, and public or private laboratories of other MNCs or small companies.

Obviously, this is a single case study of one NPD project team, in one business unit of an MNC. Our network data though are accurate at the time of collection, Spring 2007, we cannot claim any degree of being representative of all NPD projects in AMS business unit, or indeed of any other business units of the same MNC, or other semiconductor or high-tech companies. We aim, however, following up our survey and interviews with a snowball sampling approach in the near future for understanding the chains of linkages beyond the boundary of this NPD team, and over time in the life cycle of this project. We are also negotiating access for carrying out the same network survey for one of the key technological communities/competence centers, i.e., analog designers, for shifting the unit of analysis from the horizontal to the vertical axis of Fig. 3.3, and gaining insights of several projects within the same competence center and business unit, as we have identified through our interviews a great deal of overlapping memberships in NPD teams within the same business unit.

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Chapter 4
Strategies for Fostering Local New Service Development Teams in CapGemini and the MINALOGIC Cluster in Grenoble

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4.1 Introduction

It is generally accepted that more and more economic battles are being won thanks to innovation. In a world where innovation is seen as the source of progress and competitiveness, how does one innovate in a sustainable way? It is possible to consider this question in two different ways. The first way focuses on businesses and considers how these innovate. The second focuses on the industrial district or cluster and examines how the whole network of stakeholders who constitute the local "eco-system" innovates. There is no perfect superposition with regard to these two views, but rather an intersection. In fact, there is a divergence in objective and it is only possible to obtain a momentary convergence in interest between companies and district. For companies, and, in particular, large companies, a district is only one of the possible places for innovation. Large international companies aim to strengthen their competitive position, which can be achieved via relocation or outsourcing certain activities. In this context, what is the nature of this convergence in interest and how can it be strengthened? This is the underlying question this chapter poses.

Put simply, for any business, as for any district, the innovation equation can be expressed in the following way: resources – a "stockpile of technologies" and expertise – plus the ability to exploit these resources in order to transform them into innovative products and services, adding value for customers. This chapter deals with the second member of the equation: the ability to exploit the resources in question, in a context where the associated models of organization are undergoing rapid transformation. Actually, in companies – regardless of business type: large, small, or emerging – and also in districts, new models of organization have appeared for the transformation of resources into innovative products and services. These require,

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for their part, the implementation of new strategies in order to strengthen their ability to innovate in a situation of increased competition, linked to the acceleration of globalization.

The Grenoble district has been chosen as the area to be observed for this study. In this district one finds development teams from both large and small companies, as well as numerous stakeholders who contribute to local innovation. This diversity allows for the observation of various models of organization and the analysis of strategies designed and adapted to strengthen the expertise of development teams. The fact of choosing a district as the area to study also allows us to tackle the question of the links which bind together the various stakeholders, and to draw conclusions and make recommendations regarding strengthening the competitiveness of a district as regards innovation.

Two studies carried out in the past 4 years serve as a basis for this chapter. The first study (MATRI) focused on two large companies, one in the microelectronics (STMicroelectronics) sector and the other in information services (Capgemini). Both of these companies are extremely actively involved as regards development in the Grenoble district, from which they both originate. The second study (MINALOGIC) focused on collaborative development projects between state-owned R&D laboratories and big and small companies, in the framework of the development of a Grenoble competitiveness pole in the field of micro- and nanotechnologies and in software development (MINALOGIC).

Subsequently, we introduce our subject via two case studies, namely those of Capgemini and Minalogic. The former describes a new model of organization as regards the development of services in response to an emphasis on globalization. The latter does the same in an attempt to strengthen the innovative competitiveness of the district. Following on from this, we draw certain lessons as regards strategies to implement in order to strengthen local development teams. We also expound certain recommendations concerning strengthening the competitiveness of the district of Grenoble as regards the development of innovative products and services.

4.2 Two Case Studies: Capgemini and Minalogic

In the Knowledge Society, the ability to innovate constitutes a key element in districts' economic development. Now, new models of organization of the innovation value chain lead to deep changes in this ability in districts, which have historically been orientated toward innovation, such as the Grenoble district (see Annex 1).

Actually, the activities of developing innovative products and services are submitted simultaneously to both centrifugal and centripetal forces. These accelerate the change in a district's potential for innovation, without it being possible to predict whether the end result will be its strengthening or its decline.

Among the centrifugal forces figures the change of the organization of the development of innovative products and services within large industrial and service companies. Both the Capgemini case and the STMicroelectronics case, companies originating from the Grenoble district, illustrate these movements. For the former, the relocation to India of its development activities in the context of the group's globalization led to the transfer of tasks toward this country. For the latter, the reconfiguration of the microelectronic industry led to the emergence of development teams in competition within the company itself in various regions around the globe.

Among the centripetal forces figure the efforts made at a district level to encourage collaborative development of innovative products and services, following the example of the Minalogic competitiveness pole. This type of effort not only promotes a better use of technological resources among the district's stakeholders but also acts as a means of attracting new stakeholders from outside the district. The Capgemini case and the Minalogic case are developed in the following sections. The STMicroelectronics case is the subject of Chap. 3.

4.3 Capgemini: The Impact of Relocation on Models of Organization of the Development of Innovative Products and Services and on the Abilities of Local Development Teams

Capgemini was created in 1967 by Serge Kampf, a Grenoble-born entrepreneur. Over the past 40 years, it has become one of five global leaders in the field of information services and consultancy. In 2000, Capgemini acquired Ernst and Young's consulting activities, allowing the company to grow rapidly and to reach its current position as a leader in both Europe and America.

With a total of more than 80,000 employees spread out across Europe, North America, and Asia, Capgemini's operations comprise four main activities: consulting services, outsourcing services, technology services, and local professional services.

Grenoble is the company's historical location. At the beginning of 2008, Capgemini employed about 800 highly qualified employees in its premises in Montbonnot, one of Grenoble's inner suburbs.

4.3.1 Description of Capgemini's Development Process for New Products

Capgemini uses the "V-model" to describe its approach to the process of developing IT systems for its customers. This concept is widely used by companies in the information services sector. The seven steps of this process are as follows:

- Customer requirement specification – the customer's needs are formulated
- Functional requirement specification – the customer's needs are understood
- Design specifications – a solution is conceived
- Implementation – the solution is created

- Integration – the solution is assembled
- Validation – the solution is validated
- Operation and maintenance at the customer's premises – the solution is generated

The use of a "V" to depict this model relates to the way the stages are set out: The solution generated conforms to the need originally formulated. The validation is based on the functional requirement specified, and the assembly of the solution conforms to the appropriate technical design.

This representation also allows one to differentiate the tasks carried out at the customer's premises or near to the customer (the tasks at the top of the "V") from the tasks which can be completed remotely.

4.3.2 The Organization of the Innovation and Development Value Chain

For many years the dominant model in the area of IT development was that work needed to be carried out at the customer's premises and at the customer's request. Moreover, it needed to be specific to its application. The industrialization of IT services began at the end of the 1980s, under the pressure from large customers who called for increasingly complex provisions of services at increasingly lower costs. This pressure on prices, in a context of globalization, led to the development of new models of organization which included tasks carried out in offshore centers likely to provide the necessary expertise more cheaply. Initially in India, this relocation was later continued into many other countries, such as Morocco, China, Argentina, and Brazil.

In addition, the convergence of consulting activities inside organizations and the development of IT services, like the acquisition of Ernst and Young by Capgemini, illustrates the fact that the knowledge of the customer's needs and the ability of the service provider to offer and maintain solutions which best match with the customer's expectations have become the key assets that allow a company to figure among the leaders in this profession. In this context, the question put to companies in this sector is as follows: Which activities are suitable for relocation, and which models of organization should be put in place to allow for the development of the application and circulation of knowledge concerning customer needs between different sites?

4.3.3 The Rightshore™ Model

To respond to this question, Capgemini created the Rightshore™ organization model. This model calls on "onshore" resources, those closest to the customer, for example, in Grenoble for French customers, and "nearshore" resources on the same continent, for example, in Poland and Spain, and "offshore" resources, with centers in India, China, and Argentina. The first of two centers in India opened in 2001. Capgemini's activities in India were then strengthened by the acquisition of Kanbay, a global IT services company specializing in the financial services industry.

In this new model, sales and development are no longer carried out in the same country by a local development team. Instead, sales and development come under the responsibility of an integrated and multidisciplinary multinational team. Functions, tasks, and responsibilities have been reallocated between the different centers.

The Rightshore™ model combines front- and back-office operations within a global development model:

- Front-office teams, situated "onshore," manage the project and the customer relationship. As they share the customer's language and culture, they have in-depth knowledge of the customer's market and economic sector. Together with their customers, the front-office teams run what Capgemini calls the "Collaborative Business Experience." The front office covers all the activities carried out at close proximity to the customer's premises. This does not necessarily require only local resources, and can include resources in offshore countries working at the customer's premises.
- In comparison, the back office comprises all activities carried out at any site other than the customer's own. The choice of location – nearshore or offshore – is made taking into account the cost, the necessary expertise, economies of scale, and questions of productivity and quality.

To ensure the coordination of front- and back-office activities, Capgemini uses the "Distributed Delivery Framework." This is a set of standardized procedures, good practices, tools, and guides that ensure communication between the customer and development teams. The teams work online, with an industrial approach to project management, based on the implementation of shared and harmonized processes, using a shared language and mutual non-interpretable reference systems.

4.3.4 The Impact on Professions/Jobs

In order to clarify this change, eight managers representing seven countries worked together to analyze the impact of this new model on professions over the course of 2006.[1]

Three major points were highlighted:

- In most cases, responsibility for customer relations fell on the onshore team.
- Offshore development has led to changes in communication, coordination and project management, both on a front-office and a back-office level, as well as changes to both onshore and offshore.
- The transfer offshore of numerous technical aspects peculiar to the completion of projects has had repercussions on onshore roles and profiles.

[1] The project carried out by this working group was entitled IBS XV.

To give more detail, the group identified 15 generic roles covering the most frequent and important functions for conducting a project. Within the Rightshore™ mode of organization, these roles and responsibilities are distributed between onshore and offshore (see Annex 2).

4.3.5 Strengthening the Expertise of Local Development Teams

The strengthening of local development teams should feature in the company's strategic framework, as illustrated by the implementation of the Rightshore™ model, and should utilize tools which allow for human resource, expertise and company planning. At the time of this work, the totality of the roles necessary to conduct a project in the context of relocation was under review. For each role, a description of the necessary expertise to be strengthened was drawn up (see Annex 2). This description is based on the company's competency framework, with a mark allocated to each competence for each role. The only competences retained in the synthesis are those which need strengthening (those allocated a mark between two and three).

The local development teams see, therefore, their roles evolving. Technical expertise alone is no longer sufficient, and personality and behavioral traits have acquired an increasing importance. The requirements are as follows:

- A better combination of technical and economic competences.
- Communication and interpersonal know-how are of vital importance, alongside know-how associated with customer relations and teamwork.
- An understanding of how business works is important for all roles, followed by expertise in quantitative project management and industry-specific knowledge.
- Key personality traits include leadership and personal motivation.

4.3.6 Conclusion

To summarize, the working group concluded that:

- Capgemini needed to industrialize its development processes by implementing common general standards, plus shared tools and methodology.
- Managerial and leadership expertise should be developed at front-office level, so as to ensure efficient commitment with regard to customers.
- New expertise needed to be developed to promote efficiency in internal processes such as the capability to estimate the necessary resources and workload and the expertise in risk management required for numerous roles.
- Abilities in teamwork, patience, and empathy, as well as understanding and anticipating cultural differences should be developed.

4.4 Minalogic: The Impact of Collaboration at a District Level on Models of Organization of the Development of Innovative Products and Services and on the Abilities of Local Development Teams

In 2004, the French government introduced "Competitiveness Poles," in order to reinforce the French economy's competitiveness and to increase growth and employment in high-potential markets. This move was intended to increase the innovation effort, both by consolidating mainly industrial activities with high technological content within districts and by improving France's attractiveness, thanks to a strengthened visibility internationally.

The system is organized around collaborative projects which have been selected by these poles. Some of these projects are then supported within the framework of public funding.

The Grenoble district's past in the domains of microelectronics and in computer software has permitted it to be retained as a competitiveness pole under the name "Minalogic" (MIcro NAnotechnologies and LOgiciel Grenoble-Isère Compétitivité). Its purpose is to build a center on an international scale for the design of intelligent miniaturized chips, by bringing together micro–nanotechnologies and firmware technologies on these chips, and to develop these technological advances in industrial industries which can obtain a competitive advantage from them.

Three main missions make up the core of the Minalogic pole:

- The organization of the ecosystem for the competitiveness of companies in the electronic and in the firmware industries within the specific geographical zone.
- The creation and strengthening of research–industry–education synergies in the domain of intelligent and interactive miniaturized chips.
- The improvement and coordination of projects financed at a national or European level through different frameworks and platforms.

To carry out these missions, the pole, coordinated by a small team of permanent staff, offers four types of services:

- Providing new perspectives and reflection by bringing together local governments, industry, and research on techno-social subjects (intelligent roads, e-health, help for people with disabilities, etc.).
- Helping in the setting up of projects.
- Helping in sourcing funding.
- Making collaborative tools available.

At the end of 2008, Minalogic had 116 members:

- Seventy-eight companies (54 SMEs and 24 large/international companies).
- Thirteen research centers and training centers.
- Sixteen local governments.
- Six economic development bodies.
- Three private investors.

One-hundred and two research projects had been ratified, of which 68 were financed at a national level, at a total sum of 326.4 million Euros. Each project involves the constitution of a team, whose members come from various partner institutions. Each team member provides access to the resources at his or her institution. The project also relies on the competitiveness pole services listed above.

In all of these projects, the pole figures as a stakeholder and attributes itself certain activities in the development process, thereby directly contributing to value creation. Thus, the pole facilitates the setting up of collaborative projects between companies and laboratories, accompanying the project initiator to ensure that the project is accepted for funding, that it sources the best funding, and following through on the project to ensure maximum effects for SME partners and for the district, thereby spreading the good practices which came out of the monitoring of previous projects. In this way, the pole plays a major role in capitalizing on abilities as regards collaborative projects and collective learning at a district level.

4.4.1 The Level of Collaboration and Related Limits

Research into the way the competitiveness pole has functioned over its first few years has shown that the performance of a collaborative project is particularly linked to the level of collaboration between the members of the project in question:

- At the first level – called "collaboration" – partners join forces to complete the funding application. The division of tasks, the related costs, and the technical markers are clearly formulated. The technological stakes and risks are made explicit.
- At the second level – called "cooperation" – the project's strategic stakes and risks are made explicit. The project's pertinence vis-à-vis the strategy of each stakeholder is analyzed. Rules for the smooth running of the group and control mechanisms are defined.
- At the third level – called "integration" – a platform for the project is created at one of the partners' workplaces. Formal meetings take place every 6 months, with the sole aim of discussing the smooth running of the teamwork.

The first acknowledgment is that the majority of the projects stagnate at the first of these levels. In such a case, the partners involved may not realize that the project could be approached in a different way. There is little work carried out on the project team which leads to only a small sense of belonging, little free expression, dissatisfaction, and potential conflicts. In projects associating large and small companies, the SMEs may feel that they have not been listened to and develop a feeling of frustration which they have difficulties to express. There is a small amount of collective intelligence which leads to conflicts that prove difficult to manage. In the end, the project management is inefficient. The work is completed in pairs, with cooperation reduced to a minimum. The project's performance is not called into question because all its stakeholders have a personal interest in keeping the markers which concern them personally.

The second acknowledgment is that, without even speaking about performance, some projects meet with real difficulties. Funding problems appear for certain partners, such as a change in strategy due to the arrival of a new investor, made necessary by the financial situation of the company in question. Difficulties linked to incompatible economic models between SMEs and “flagship” large international companies can render a consortium agreement impossible and lead to the project blocking. In the end, the objectives and the motivations of each of the partners, which are sometimes divergent, are not closely examined at the project’s outset. If there is an imbalance in the power relationship between the partners, the SME can risk becoming the casualty of the other stakeholders’ choices. This is the case when the research laboratory’s objective is to eventually set up a new industrial subsidiary, the SME’s objective is to diversify and to find short-term business opportunities. Another example is when industrialists’ objectives are different and it is difficult to reconcile the two: monitoring the technological competition for some of them and the objective of finding new business opportunities for others.

4.4.2 Strengthening the Performance of Local Development Teams in the Framework of Collaborative Projects

The question regarding strengthening the performance of local development teams in the framework of collaborative projects can be approached from two complementary points of view. First, it can be considered from the point of view of the project and, second, from the point of view of each company, and particularly the SME, participating in this.

4.4.3 Strengthening Performance: From the Point of View of the Project

Learning from the above limits in collaboration shows that the following abilities are necessary for the success of the collaborative projects:

- Abilities in sharing, debating, and negotiating with regard to four areas of contribution: scientific, industrial, marketing, and project management.
- Abilities to cooperate of the different stakeholders.
- Abilities to pilot projects in a context of open innovation.
- Abilities to take into account the question of marketing at the very early stages of the project.

Annex 3 puts forward a list of abilities associated with the four areas of contribution: scientific, industrial, marketing, and project management.

4.4.4 Strengthening Performance: From the Point of View of the SMEs Participating in the Project

The success of a collaborative project also depends on the ability of the SMEs involved to participate in the project and to make the most of the results by streamlining their distinctive competencies.

Five main contributions are expounded: a monitoring of the environment, learning how to work in a partnership, defending one's interests, internal organization, and an optimization of the spin-offs of the project in question. Annex 4 puts forward a list of associated abilities.

4.4.5 Capitalizing on Abilities and Collective Learning at a District Level

The competency framework in Annex 3 complemented by the list in Annex 4 is a first attempt to develop such a tool at the district level. Up to then, in the domain of HRM, few changes had taken place with regard to the observation made in 2006 by Culie et al. "The human dimension within Minalogic is to an extent in the image of HRM to be found in the literature on clusters: HRM is present in an underground way, allusive and essentially informal" (Jean-Denis et al. 2006). The development of abilities did not, therefore, have an organizational framework in the image of that which can exist within large international companies. In the collaborative projects in which large international companies participate, these latter bring with them – and often indeed impose – their abilities in project management, their methods, and their tools. The learning acquired by SMEs remained limited to the people participating in the collaborative projects. They can have difficulties to transpose the methods and tools conceived into a different context, making capitalizing on abilities and collective learning at a district level difficult.

4.5 Learning and Recommendations for Strengthening the Ability to Innovate in Local Teams

The above sections illustrate the emergence of new models of organization which structure the stakeholders involved in the innovation value chain differently.

Whether it is in the case of Capgemini or that of Minalogic, the project team – the momentary aggregation of resources and the place of transformation of these resources into value for the customer – is the holder of the ability to make the most of local and global resources which determines the company's or the district's performance in terms of the development of innovative products and services. Therefore, the following sections focus on how to strengthen the project teams.

This project team must be situated within the entities which make up its environment and which determine, on the one hand, its missions, i.e., the business unit for which the innovative product or service is being developed, and, on the other hand, the means which it will have at its disposal for the fulfillment of these missions, i.e., the resource centers.[2] This simple representation of the project teams as between resource centers and business units allows for the formulation of questions regarding the strengthening of innovation abilities at a district level.

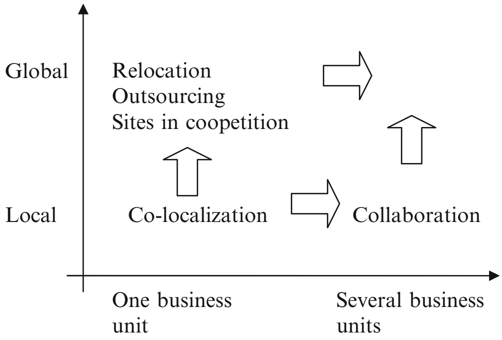
The Capgemini case illustrates the impact of relocation on project teams in the case where a business unit serves global markets and where its management is located outside of the Grenoble district. Several development teams compete with one another to be allocated the whole or part of the project. The dividing line for activities with regard to where they are located is determined by the "V Cycle." The activities that are upward and downward in the process are located close to the customer. The intermediary activities are offshore. The principles which govern this division impose themselves in the same way from one project to another. It is cost/performance considerations which promote the relocation of intermediary tasks and the necessity of proximity to customers which imposes the fulfillment of upward and downward tasks close to or, indeed, at the customer's premises. In this typical case of relocation, there is no externalization of activities, and the totality of the development process remains within the legal boundaries of the company. The links between project teams and external resources centers at a district level are limited.

In the case of Capgemini, as in all the cases where the decision to allocate projects and/or tasks within the projects is taken outside of the district and where it answers to various criteria linked to the proximity of markets, to the cost, or to the performance of the required resources, the stake for the district is to ensure that local teams have competitive advantages at their disposal, in order that the allocation decisions are in their favor. As it cannot be in the case of the Grenoble district a question of an advantage based on costs, and independently of the proximity of the markets, it is the performance in the putting into place of resources which can make the difference. This latter depends on the innovation abilities of the local project teams within the company and those of the local resource centers with which they linked; hence, the importance of the district anchorage of the teams in question. Without a strong anchorage, project teams call more and more frequently on resource centers outside the region. As a result, the center of gravity swings, and the project teams themselves are finally delocalized.

In the case of Minalogic, the collaborative projects introduce another model. The business units and the project teams are concentrated within the one district. The project teams are made up of the momentary aggregation of resources which come from local stakeholders, international large companies, SMEs, research laboratories, and institutional intermediaries. The first characteristic of this model is that it is, in essence, local as opposed to the case of Capgemini which is, in essence, global. The second characteristic is that the projects are integrated into the innovation

[2] For further developments see Annex 5.

Fig. 4.1 From colocalization to global models of innovation



strategy of several stakeholders – several business units – while in the precedent case, the project team came under one single business unit. This second consideration leads to specific difficulties: How to cooperate in a context where the goals aimed for by different partners are in fact divergent?

In this case, the stakes for the district are principally of two natures. Namely, it is necessary to ensure that the company acquires the abilities that are necessary in order to participate successfully in a collaborative project, while also ensuring that its strategic position develops, so that it takes full advantage of the project in terms of distinctive competencies. In returns for this, a virtuous circle is established which ensures simultaneously the strengthening of both the business units and the district to which these belong.

These two cases, without being exhaustive, describe new models of the organization of the innovation value chain which coexist at a district level and which link between them the stakeholders of the local innovation system. Apparently disconnected in their stakes for the district, the two cases discussed above are obviously linked. Without international large companies' resources centers, and without the breeding ground of innovative SMEs, there is little chance of seeing the other district resource centers like research laboratories develop.

Figure 4.1 illustrates this progression: from the original model (colocalization) where the project team was made up exclusively on the basis of local resources within one single business unit, toward the models described above[3] with a potential progression toward global models bringing together several business units.

[3] The STMicroelectronics case study, which is not discussed above, illustrates development toward a model that combines relocation, outsourcing, and "coopetition" between design sites within the one company. Initially based on project teams concentrated in the one place, the model first evolved toward a model entitled "central site with satellites," where diverse stakeholders– relocation plus outsourcing – intervene and to which the central site subcontracts part of its tasks while still retaining the overall project management. Then under the effect of the reorganization of the value chain, the model of organization evolved toward a model of "networked centers" within the company, each central site being both in competition with the others in terms of the management of development projects, and in a situation of cooperation for their fulfillment (coopetition).

4.5.1 Strengthening Innovation Ability at a District Level

Strengthening innovation ability at a district level necessitates the development of new abilities linked to the mastery of the new models of organization of the innovation value chains. These abilities are of an individual, collective and institutional nature. This strengthening also necessitates the appropriation of methods and tools and the putting into place of adequate principles of organization.

As far as abilities are concerned, in the case of local collaborative models, it is a question of ensuring that, on the one hand, the project teams have the abilities required for the success of a collaborative project i.e., project management abilities, plus individual and collective abilities linked to the collaborative dimension of projects. Then, on the other hand, for local business units – in particular the SMEs linked with the collaborative projects – it is a question of ensuring that these have the necessary abilities for the development of their strategic position, in order to make sure that they get a maximum from the projects in which they participate i.e., the ability to increase their distinctive competencies, their iteration and capitalization ability.

In the case of global models, it is a question of ensuring that local teams have abilities that are likely to bring them a competitive advantage to make decisions regarding the allocation of projects in their favor. This latter depends on the innovation abilities of the company's local project teams: abilities in project management, plus individual aptitudes linked to the global dimension of projects, key collective abilities in team projects, mastery of key roles. It also depends on the innovation abilities of the local resource centers with which they are linked.

In conclusion on the subject of abilities, strengthening the district's ability to innovate is to strengthen the abilities of the local stakeholders in the above different directions. This can be seen as a pyramid to be built, which is made out of successive strata of individual, collective and institutional abilities (see Fig. 4.2).

4.5.2 Project Management Abilities

These are the basic abilities which the project team members need to possess. They are described in numerous textbooks on this subject. These abilities remain applicable regardless of the model of organization of the innovation value chain. They have been described in the MINALOGIC case through four areas of contribution: scientific/technological, industrial, market, management (see Annex 3). Each task was the object of descriptive forms detailing the abilities necessary which together constitute a competency framework.

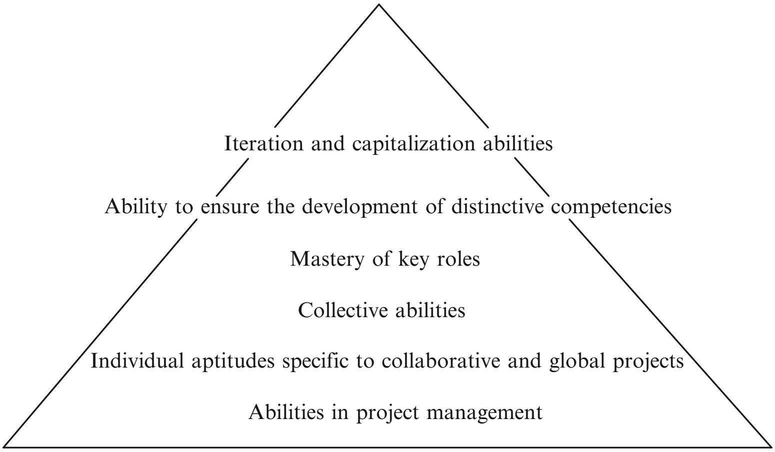


Fig. 4.2 Individual, collective and institutional abilities contributing in a district's innovation ability

4.5.3 Individual Aptitudes Specific to Collaborative and Global Projects

In addition to the project management abilities discussed above, the new models of organization call on members of the project teams to have specific aptitudes. In the case of collaborative projects, project teams are confronted with possible difficulties linked to the sharing of activities between partners who do not have common practices in this area, and who may use different methods and tools, and who possibly are pursuing different objectives. These possible divergences mean that project members require aptitudes in sharing, in debating, in negotiation and in cooperation.

In the case of "global" projects, team members need to work at a distance, in a multicultural context, and with weakened reporting lines. The Capgemini case in particular highlights the necessary individual aptitudes: a better combination of technical and economical abilities, know-how in the area of interpersonal communication and cultural understanding, a team spirit, abilities to resolve problems and conflicts, risk management, and personality traits including leadership, personal motivation, patience, empathy, etc.

4.5.4 Collective Abilities

The literature has emphasized the importance of collective abilities (Courlet 2008), in the face of the growing complexity of new models of organization. The key words are cooperation in competition, pooling learning, and confidence, as well as factors conditioning the collective ability to integrate the project team members' knowledge and that of associated resource centers and to make value out of them in a dynamic way.

The Capgemini case underlines the abilities which concern customer relations, an understanding of business, and industry-specific knowledge, those which concern team work, plus those which relate to quantitative project management. The STMicroelectronics case has allowed for a more detailed description of collective abilities within project teams.

4.5.5 Mastering Key Roles

The literature (Cohen and Levinthal 1990; Sanchez and Mahoney 1996; Cross et al. 2002; Oswald 2006), as in the cases studied, highlights the importance of key roles in new models of organization. These roles are associated with the mastery of tasks which bring a high level of added value within projects. They are, in particular, those tasks which underlie the ability to integrate the knowledge of the various project team members and that of the resource centers linked to the project and to make value out of it in a dynamic way.

The characteristics of these roles are that they are carried out within often informal networks and that they need often to be shared between several stakeholders. The conditions underlying the effective carrying out of roles – cooperation in competition, pooling learning, and confidence, to take the terms from the previous paragraph – naturally lead to the accent being put on the shared dimension of these roles.

As a consequence, these roles do not easily lead themselves to description or management. The way in which these roles are carried out can be on the verge of being ignored by management. Job descriptions – when these exist – are created by the companies' human resource management teams, and designed following a process and not a network rationale. As a result, these often convey these roles in an incomplete manner. Actually, these descriptions are conceived on the one hand in order to meet the need to accomplish tasks associated to business processes thus allocating individual responsibilities which deduces the necessary abilities, and on the other hand, in order to meet the necessities of the career management of these same individuals. Consequently, they describe the individual abilities associated with the tasks to be completed well, but have more difficulty in describing the ability to integrate the knowledge of the project team members and those of the resource centers linked to the project and to make value out of it in a dynamic way.

The growing importance of these roles means that their mastery is a major stake for the strengthening of local innovative product and service development teams.

4.5.6 The Ability to Ensure the Development of Distinctive Competencies

The partner SMEs in collaborative projects, but also the business units within international large companies when these are local, need to have at their disposition the necessary abilities in order to develop their strategic position, so that they get a maximum from the projects in which they participate. This is one of the key success factors peculiar to innovative companies, to know how to permanently adjust their supply and demand: to commit themselves to development projects which correspond to their specific markets and, in return, to ensure the development and alignment of these markets and the company's organization to correspond to the technological opportunities and the resulting products and services (Michel Callon 1988; Tidd et al. 2001).[4] This is a question of combining both the key roles of "business developer" and strategist which can only be held, in particular in innovative SMEs, at the highest levels of organization.

4.5.7 Iteration and Capitalization Abilities

All the descriptive models of innovation value chains highlight the importance of a learning phase and of "re-innovation," in a feedback loop, which shows that a company's ability to innovate cannot be reduced to a single product or service, but instead that it is about a cumulative process.

The business units in international large organizations have often integrated this learning process and that of capitalization, on the one hand, by project reviews once finished, in order to obtain a maximum of lessons from the project, and on the other hand, by the presence within project teams of representatives (team leaders) from each resource center who have the dual mission of supervising his or her team's work and monitoring the return of knowledge acquisition toward his or her resource center. The cooptation of "team leaders" within successive projects' "core teams" provides a perennial skeleton to learning and capitalization.

In the case of collaborative projects at a district level, pooling and capitalizing on learning collide initially with stagnation at the first level of collaboration – see the Minalogic case – of the majority of collaborative projects. Next, they come up against the absence of continuity in companies' participation in successive projects. This is particularly the case with SMEs. The setting up of the structures of the Minalogic competitiveness pole and the efforts they make to ensure that projects develop toward the more advanced levels of collaboration – "cooperation" then "integration" – make up in particular, but only in part, for this lack.

[4] For Michel Callon, the key words to the success of innovation are: interactions, the circulation of information, consultation, adaptation, decompartmentalization, and suppleness: "Innovation's destiny, its contents but also its chances of success, reside entirely in the choice of representatives or spokespersons who are going to interact, negotiate in order to get the project into shape and transform it until it builds a market." Callon introduces here the idea of a key role in the innovation process. This is the role of the "spokesperson," the project stakeholder who is able to link the technology and the market. This idea has been taken up once more and developed in the recent work on "open innovation" (Chesbrough 2003).

4.5.8 The Appropriation of Methods and Tools and the Setting Up of Adequate Principals of Organization

Several further factors which are necessary in the strengthening of innovation abilities in project teams at a district level also require consideration in more detail than this chapter allow. These revolve around the methods and tools and principals of organization which will allow for the efficient exploitation of the abilities developed.

The Capgemini case highlights the importance of the “distributed delivery framework,” a standardized set of procedures, good practices, tools and a guide which facilitate communication between customers and development teams. The equivalent is also necessary at the level of collaborative projects within the district.

Numerous tools exist at the level of large international companies for employment and ability planning: competency frameworks, job evaluation, “roadmaps” structuring jobs in relation to one another and allowing one to visualize career pathways within the company. The equivalent (management of jobs and abilities within the district) is also necessary at a district level (Baron and Bruggeman 2009) along with links between the two.[5]

More broadly speaking, human resource management is called into question. In general, local HR services within large international companies do not have the strengthening of the distinctive competencies of local development teams, as opposed to those of other development teams within the company, as part of their remit; nor do they have the remit to focus on the development and local anchoring of these teams, always with the aim of strengthening the district to which they belong. This is even more true if the management of business units is not located in the district. There is, therefore, a significant undertaking, for which the ins and outs have yet to be established, in order to favor the local setting up of decision-making centers for business units in the case of large international companies. Consequently, there is also a real undertaking to direct the missions of local HR departments toward the strengthening of distinctive competencies of the local development teams and their local anchoring through participation in district-level management of abilities. The equivalent is also necessary at a district level and within the SMEs which make this up, through the intervention of the competitiveness pole.

Finally, the integration of the district project teams within an “archipelago network” (Veltz 2008)[6] of international competitiveness poles sets a long-term goal for all the district stakeholders involved in the strengthening of its innovation ability.

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[5] See the experiment currently in process at the “mobility pole,” which has for its purpose to promote the development of people within and between companies in the Grenoble district.

[6] See also in this regard the development tentatives of the “Knowledge and Innovation Communities” (KICs) set up by the European Commission (European Institute of Innovation and Technology – EIT).

4.6 Concluding Thoughts

In these new models of organization of innovation value chains, the key success factors are less the ability to control within one single geographical entity the totality of the technologies implemented in the innovation process, and more the ability to join forces and to source from outside the knowledge and abilities which this entity needs in order to carry out its role in the innovation value chain. “It is no longer technology which is the strategic resource. Indeed, it is the technological and cognitive organizational processes which underlie the abilities to innovate and to learn” (Moingeon and Edmondson 1996).

This chapter has mainly focused on the question of developing innovation abilities. It constitutes a sort of set of requirements for an innovation ecosystem. It also provides some avenues to be explored for the stakeholders in local development, and, in particular, for the competitiveness poles which have recently been set up.

Annex 1 The Grenoble District and Innovation

Grenoble’s development started in the 1870s, with an emphasis on hydraulic resources. With this came the development of machines and equipment, for the production, conversion, and supplying of electricity. As part of the resulting boom, industries which consumed large quantities of electricity established themselves in the region, such as the paper pulping industry. New technologies quickly find a market here and scientific and technical knowledge are oriented toward concrete applications.

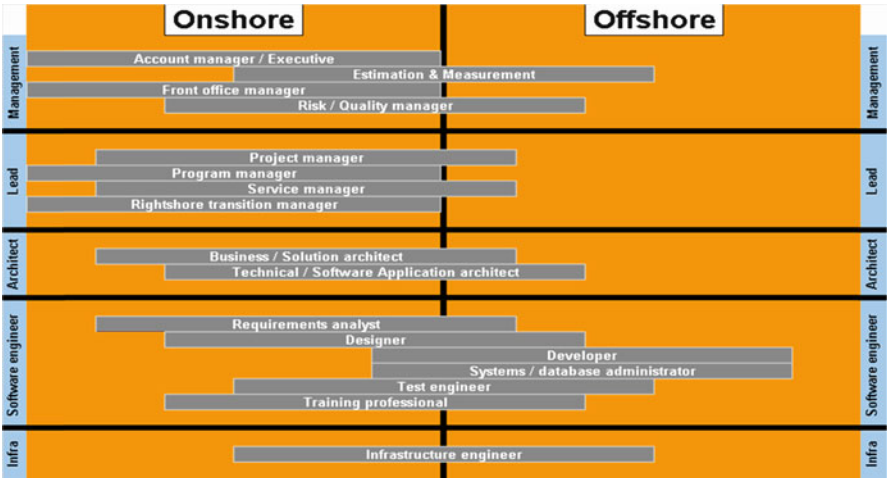
The industrial development fed the development of universities, engineering and management schools, and research laboratories. In particular, this included the creation of the Grenoble center for nuclear studies, which has become the Grenoble CEA, which quickly acquired a high level of competence in nuclear physics.

Large international companies with a worldwide remit gave rise to economic development in the Grenoble basin. These include the energy giant Schneider Electric which has one of its major roots in the Grenoble company Merlin Gérin, Capgemini in the IT services sector, and STMicroelectronics in the microelectronics area through EFCIS, its first MOS activity/business. The setting up of these large industrial companies encouraged the emergence of numerous innovative SMEs.

Consequently, the Grenoble district gathers together all of the stakeholders likely to contribute to the innovation value chain in the high-tech industries, such as micro- and nanotechnology, biotechnology, and software development. Its potential in terms of the development of innovative products and services is one of the strong characteristics of the Grenoble district.

Annex 2 The Division of Key Roles Between Onshore and Offshore and the Abilities to Be Strengthened in the Capgemini Case (Source: Capgemini)

Division of Roles and Responsibilities in the Rightshore™ Project



Synthesis of the Abilities to Be Strengthened in the Framework of the Rightshore™ Model of Organization

	Account Manager / Executive	Estimation & Measurement	Front Office Manager	Risk / Quality Manager	Programme / Project / Service Manager	Rightshore Transition Manager	Business / Solution Architect	Technical / Software Application Archite	Requirements Analyst	Designer	Developer	System / Database Administrator	Test Engineer	Training Professional	Infrastructure Engineer
Architecture and design							3,0	3,0	3,0	2,7		2,3	2,0		2,0
Business and financial management	2,3		3,0												
Capgemini tools and methods	2,0		2,7	2,7	2,7	2,7	2,3	2,3	2,3	3,0	2,7				
Change management			2,7		2,7										
Client management			2,7		3,0	2,3									
Estimating		3,0	2,3	2,7	2,7		2,3	2,3							
General business knowledge	3,0														
Industry specific knowledge	2,3													2,3	
Process standards				3,0	3,0					2,3					
Programming skills								2,7		3,0	3,0	2,7			
Qualitative project management			2,7	2,7	3,0	2,7									
Risk management	2,3	2,7	3,0	3,0	3,0	2,7									
SDLC		2,7	3,0	3,0	3,0		2,3	2,7	2,7	3,0	3,0	2,7	3,0		
Controlling and managing scope / Planning and organisation			3,0	3,0	3,0	2,7									
Cultural understanding / Innovation change and accountability	2,7		2,3		2,3	2,3									
Leadership / People management															
Problem solving / Decision making / Conflict resolution	2,7		3,0	2,7	3,0	3,0									
Teamwork / Communication and interpersonal skills	2,3		3,0		3,0	3,0			2,7					2,7	
Energy, motivation and resilience / Personal motivation	3,0		3,0		3,0	3,0			2,7				2,7	3,0	
Level of extroversion	2,7				3,0									3,0	
Patience / Empathy	2,7		3,0		3,0	3,0			2,7					2,7	

Annex 3 A List of the Abilities Linked to Collaborative Project Management

Scientific/technological abilities:

- Mobilizing the best experts and bringing them to explore scientific bottlenecks.
- Compiling "BATs" and leading on monitoring technological and scientific development.

- Adopting a "systems" approach which allows for the comprehending of specific technology as a whole and integrating extremely diverse building blocks with complexity in their correlations and interfaces.
- Drawing up a development plan.
- Drawing up sturdy processes for developing technology in order to produce a robust prototype.

Industrial abilities:

- Defining technical specifications and feasible performance levels.
- Taking into account, from the development stage, the problematics of industrialization and maintenance – product methods, monitoring manufacture, equipment, security, environment, etc.
- Taking into account from the development stage, the industrial norms currently in force – medical norms, electrical, electromagnetic compatability, etc. – in order to design a product which is likely to pass qualification stages.
- Carrying out "patent" monitoring and developing an IP strategy.
- Anticipating production costs and levels of industrial performance that are attainable.
- Preparing specifications for the future experimental production line.
- Developing partnership with suppliers of raw materials and manufacturers.

Market abilities:

- Analyzing the competitive environment.
- Identifying potential customers and meeting with these to exchange on future applications.
- Envisaging all application possibilities and organizing these into a hierarchy.
- Anticipating the potential markets for these applications.
- Taking into account the question of "time to market."
- Researching suppliers/partners for the future commercialization of products.
- Being integrated or integrating oneself into a "professional network."

Management abilities:

- Creating the necessary conditions for the cohesion of the project team.
- Creating the necessary conditions to exert one's leadership.
- Promoting the convergence of scientific, industrial, and marketing logic.
- Compiling the project workplan.
- Managing the project's progress.
- Managing partners' commitments fairly in terms of resources.
- Establishing strong communication links with the senior managers of partner companies, customers, support functions, and contractual entities.

Each of these abilities was the subject of an information form. Together, these forms constitute a competency framework.

Annex 4 A List of the Abilities Associated with the Exploitation of the Results of Collaborative Projects

Monitoring the environment:

- Conducting a strategic analysis of the environment.
- Conducting an analysis on the strengths/weaknesses of the SME's technology.
- Acquiring the knowledge of state-of the-art techniques.

Learning of partnership:

- Analyzing the real motivations to bring in a project and the associated risks.
- Developing a true ability to share.
- Knowing how to identify the right partners.

Defending interests:

- Evaluating the level of protection of one's know-how.
- Evaluating the risks and stakes of the intellectual property of one's project.
- Negotiating effectively the agreement of the consortium.

Internal organization:

- Knowing how to anticipate potential funding problems.
- Anticipating a plan to gain further funding if necessary and putting together a fundraising bid.
- Identifying missing abilities and recruiting or training the right people to ensure the project succeeds.

Optimization of the project's spin-offs:

- Putting to work the project team as quickly as possible.
- Adapting classic project management so as to keep creativity, and managing the risks and uncertainties peculiar to innovation.
- Anticipating the customer's needs in emerging markets and/or the possible uses of a new technology.

Annex 5 The Project Team Between Business Unit and Resource Centers

The development of innovative products and services is carried out within the organizational framework of a business unit. In strategic analysis, in the way that this is typically practiced, the problem of the business unit lies in the development of a "distinctive" competence, in line with key success factors in the markets which it targets. The creation of a distinctive competence is imperative for the survival of the business unit and this imposes itself on the totality of the teams which constitute or contribute to the business unit. The development of innovative products and services comes up against the business unit's distinctive competence and are decided, as a result, by the management of the business units.

The resources mobilized by the project team and the abilities put to work in order to transform these into value for the customer are, therefore, closely linked to this positioning. The resource centers will provide the resources needed by the project team. The term "resource" also extends to physical resources (technologies, equipment, etc.), human resources (knowledge, intelligence, networking, etc.), and organizational resources, based on which the project team can develop an innovative product and service. These resources centers gather together people sharing the same profession (test) or the same technological specialization (optoelectronic) or managerial area (sourcing). They can be formal or informal structures, which are internal or external to the company, which can be seen as a pool from which the project teams come to momentarily draw the resources that they need.

The alignment of the means (resources) and the ends (distinctive competence) is facilitated when the resource centers are within the company and when there is both proximity and a hierarchical dependence.

Now, the new models of organization lead the project teams to mobilize resources that are external to their company in two ways. On the one hand, a part of the tasks can be outsourced by having recourse to partners (suppliers, research laboratories, etc.). On the other hand, to fulfill tasks that are not outsourced, team members call on resources which do not belong to the business unit (for example, by having recourse to the knowledge of a community of experts via their personal networks).

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Chapter 5
Regional Embeddedness of Multinational Enterprises in European Regions

Knut Koschatzky, Andrea Zenker, and Elisabeth Baier

5.1 Introduction

It is often argued that multinational enterprises (MNEs) act spaceless in the global economy and that they are an essential mechanism in the internationalization of the transfer of knowledge and technologies. The existence of international inner-organizational learning and synergy effects distinguishes MNEs from market-based exchange relationships and national companies (Narula and Zanfei 2005). With their knowledge-accumulating and -processing capacities, MNEs can use product, production, distribution and development competences, which they accumulated in their homeland and in all other socio-cultural and institutional contexts where branch plants are located. In this respect, MNEs can combine the advantages of globally coordinated product and production strategies with the advantages of local proximity and specific locational factors (Cantwell and Mudambi 2000).

The assumption is put forward in this contribution that MNEs are not per se footloose, as often argued (cf. Görg and Strobl 2003), but through their different tangible and intangible interactions with other firms, research institutes, the political and administrative system; with intermediaries; and with the labor market they are, to a certain extent, embedded in regional environments (e.g., in the way of "being there," exploiting the "local buzz," and exploiting advantages of regional interconnectedness; cf. Gertler 1995; Bathelt et al. 2004; Bunnell and Coe 2001), favoring spatial agglomerations as their location (Cantwell and Piscitello 2002).

This contribution deals with the regional embeddedness of MNEs in their innovation activities. Based on the systemic characteristics of innovation processes, it will be shown in Sect. 5.2 that innovation has a context specificity and that this

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context specificity is also shaped by the factor endowment of the region in which an MNE is located. In Sect. 5.3, results from a cluster analysis for 215 European regions will be discussed. The three identified clusters depict those regional characteristics which show either a high or a low propensity for the location of MNEs and for which a high or low regional embeddedness of the enterprises could be anticipated.

5.2 Regional Embeddedness and Innovative Activity

5.2.1 Regional Embeddedness

The territorial setting, defined by the special characteristics of the location of a firm or a branch plant, matters for the economic and innovative activity of this territory (Porter 1990). Depending on their size, their sector, and the national or regional environments, firms depend differently on external factors and incorporate them to a different extent into their innovation activities (Gertler 1995; Koschatzky and Zenker 1999). Particularly for MNEs, the question can be raised whether they focus on the exploitation of their global networks or whether the regional factor endowment of the different branch plants is also important for them (Coe et al. 2004). It will be argued here that spatial influences exist by which MNEs exploit and utilize different location-specific and market-related factors (Cantwell and Piscitello 2002, p. 70).

"Region" in the context of embeddedness is understood as "authentic community of interest," i.e., as economical and political action framework, which is characterized by common normative interests, economic specificity, and administrative homogeneity (Ohmae 1995). As such, the region can represent a possible action field for the economic activity of firms, while "embeddedness" refers to the territorial integration and networking processes within the territory. According to Hess (2004), this concept includes all types of actors' integration with regional/local social networks and regional social relationships. Important to note is that embeddedness should not be mixed with stickiness in a way that it describes a phenomenon where actors are solely regionally integrated. It should not be interpreted as a regional or local lock-in situation (according to the concept of Grabher 1993), but in line with Hess (2004, p. 177) as an open system of embeddedness in which its social aspect ("social embeddedness") refers to how actors are shaped by their values and cultures, its network aspect ("network embeddedness") stresses the local, regional and nonregional networks of the regional actors, and its territorial aspect ("territorial embeddedness") refers to the links of the regional actors with their regional and interregional environments. Here, the focus is on the territorial embeddedness. It should denote the degree of the exploitation of both regional and nonregional knowledge sources which are relevant for innovation, process, and product development.

5.2.2 *Basic Characteristics of Innovative Activity*

According to the recent understanding in innovation economics, innovation is an evolutionary, cumulative, and interactive process of the transfer of information, and implicit and explicit knowledge to new technological, social, and organizational solutions (Nelson and Winter 1982; Dosi 1988; Freeman and Soete 1997; Koschatzky 2001). Embedded in the conceptions of evolutionary economics, this innovation concept is based on the assumption of evolving structures, bounded rationality, opportunistic behaviors of economic actors and particularly uncertainty, i.e., complex and unstable production environments, and information asymmetries as well as cumulative learning processes. The economic structure is characterized by growing variety and complexity through the development of technologies, organizations and firms. Innovation in this context is conceived as process of problem solving (cf., for instance, Lambooy and Boschma 2001, pp. 114–118; Muller 2001, pp. 5–6; Camagni 1991, pp. 214ff.; Bathelt and Glückler 2002, pp. 195/196 and 237ff.). Evolutionary economics assumes that economic actors and the economic structure are interrelated and mutually influence each other. New technologies, products, organizations, and institutions lead to a new variety and increasing complexity of the environment, effecting evolution and economic growth. Nevertheless, firms behave according to established "routines" in order to reduce risk and uncertainty instead of switching to new technologies (Nelson and Winter 1982). This may lead to suboptimal market configurations.

The understanding of innovation as interlinked and cumulative process also refers to multiple and diverse knowledge sources, which are important for a successful innovation project (Drucker 1985, p. 102). This complex process can hardly be achieved by individual firms; they are, instead, assumed to rely on diverse inputs in order to introduce inventions to the market. Innovation is thus strongly based on both knowledge and learning processes. These knowledge generation and implementation processes are supposed to result from social interaction between economic actors; it is assumed that "… firms almost never innovate in isolation" (Edquist 1997, p. 1). They rather network with further actors in order to access and complement knowledge pertinent to the innovation project in question and to generate new knowledge. A network is understood as "… a closed set of selected and explicit linkages with preferential partners in a firm's space of complementary assets and market relationships, having as a major goal the reduction of static and dynamic uncertainty" (Camagni 1991, p. 230). Innovation networks are specifically directed towards innovation; they involve different actors with the objective to realize an innovative activity. Geographical and social proximity strongly facilitate those interactions between innovation partners (Koschatzky 2001, pp. 120ff. and 145ff.). Decisive in this respect is the differentiation between codified (explicit) and tacit (implicit) knowledge. While the latter type of knowledge is stored with the help of a code which requires the "translation" of knowledge into a distinct codified form, the tacit type of knowledge is not coded in such a way and is therefore closely related to the knowledge creator. Polanyi (1997, p. 136) clearly referred to the significance of tacit knowledge in saying that "we can know more than we can tell." Tacit and codified knowledge types are closely interrelated, since the generation and understanding of codified knowledge are coupled with and require tacit knowledge. Senker (1995, p. 426) described tacit knowledge as "heuristic, subjective and internalized" – thus related to the knowledge creator – which is "… not easy to communicate and is learned through practical examples, experience and practice." Contrary to tacit knowledge, codified or articulated knowledge "… is transmittable in formal, systematic language" (ibid, p. 426). While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Knowledge creation based on interactions and transformations between tacit and codified knowledge (knowledge conversion) is considered as firms' crucial function by Nonaka et al. (2000). Processes of knowledge conversions lead to a constant evolution of firms (cf. Nonaka et al. 2000, p. 10). Knowledge creation and exploitation can be stimulated by being closely located to relevant knowledge sources and by exploiting the advantages of the "local buzz" of learning and knowledge-generating processes (Bathelt et al. 2004). According to Cantwell and Piscitello (2002, pp. 69–70), "the existing knowledge base of a region plays an important role in the decisions of the largest foreign-owned firms as to where to locate their technological activities as well as other location-specific factors mainly related to the market."

5.2.3 Context Specificity of Innovation

Most innovation processes are context-specific, i.e., they depend on the larger framework in which they take place. Two major aspects of contextuality are highlighted in the theoretical debate: the territorial and the sectoral aspect. The territorial aspect can be grasped by the concept of regional innovation systems. In general, systems of innovation are defined by "…all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovation" (Edquist 2005, p. 182). The major focus lies on the institutional set-up defined by national boundaries and the factors influencing innovative activity at the national scale. Regional systems are not an image of national systems, but respond to different rationales, and institutional and governance settings which can be found at the subnational territorial level. It is a distinct element of the concept that a region does not offer all factors and institutions necessary for innovation, but that it is a part of a superior, i.e., national system, and has to cooperate with other regional or national systems in order to merge all necessary resources at the specific territory (Cooke et al. 2004; Asheim and Gertler 2005). The territorial (national or regional) systems of innovation approach emphasize the relevance of localized framework conditions for the generation and diffusion of technologies and define contingency with regard to a geographic perspective. From a regional viewpoint, MNEs are the most important economic agents for the integration of a region into global networks. The success of regional networks depends on whether a region will become a

"Neo-Marshallian node" in national and global information, communication, investment, and production networks (Amin and Thrift 1992). Taking the example of the Silicon Valley, Gordon (1995, p. 195) analyzed such network nodes and concluded: "industrial districts or innovative milieux are compelled to integrate extra-regional contributions as an essential component of the regional innovation process itself." Such "extra-regional" linkages are coordinated to a considerable extent by international or global corporations: "MNE as one of the critical channels for organizing cross-border asset-seeking and asset-exploiting activities not only between different nation states, but also between micro-regions within different states" (Dunning 2000, p. 29).

The sectoral innovation system specifically focuses on the framework conditions in a particular industry (Breschi and Malerba 1997). It emphasizes that actors belonging to a certain sector have sector-specific knowledge and use sector-specific technologies, and that market relations, the institutional context, actors' behaviors, etc., are specific in these sectors. Sectoral innovation, however, is not spaceless, but rooted in a multi-territorial system in which different locations and their institutional fabric influence innovative activity in a specific manner. One aspect of this multi-territoriality is global research networks organized within large firms (Zander and Sölvell 2000; Ghoshal and Bartlett 1990). Related to the multi-territoriality of innovation, it can be concluded that a view towards different niches, which could be interpreted as different regional or even national institutional settings, is essential in order to obtain a more comprehensive picture and understanding of actors, networks and institutions that contribute to the overall technological and sectoral system. According to Markard and Truffer (2008), such a framework could offer a series of benefits, especially with regard to the explanation of technological transformations and transitions.

5.2.4 MNEs and Regional Embeddedness

From a theoretical point of view, the question could be raised why companies in their geographical diversification strategies opt for inner-organizational forms of control and coordination and not for market-based forms of coordination, such as exports or franchising (Dunning 1988). In a static perspective, the answer lies in transaction cost advantages of organizations; in a dynamic perspective, the major advantages of MNEs are the greater flexibility (Buckley and Casson 1998) and the cross-border utilization of technological and organizational competences (cf. Granstrand and Sjörlander 1992; Scaperlanda 1993; Howells 1990; Zander 1998; Kogut and Zander 1993, p. 631; Shimizutani and Todo 2008; Ito and Wakasugi 2007). Through internationalization and the exploitation of globally available assets, enterprises attempt to use their specific competences in several markets and are thus "footloose" in nature (cf. Chandler 1992; Zander and Sölvell 2000; Görg and Strobl 2003). In an ideal situation, companies could combine the advantages of globally coordinated product and production strategies with the advantages of local proximity and specific locational factors (Cantwell and Mudambi 2000). MNEs can therefore be characterized by a reciprocal exchange between different national subsidiaries. Local, regional, and global networks coexist as a result of the interplay of spatial focus in the overall strategy, network capabilities, and innovation intensity (Bunnell and Coe 2001; Geenhuizen 2007). While most large firms are global in nature, others may have a focus towards a few regions or countries. The relationship between the firm and the region, i.e., its embeddedness, will therefore differ from case to case, and thus also the degree of "footlooseness." Some firms may indeed make use of globally dispersed knowledge sources, while others are more strongly bound to certain regions (von Zedtwitz and Gassmann 2002). These strategies depend on the necessity of the firms to get access to specific localized knowledge and skills, on their ability to become a player in the regional innovation system or a cluster and to get direct access to specific markets (Andersen and Christensen 2005; Enright 2000). In this respect, MNEs are dependent on the quality of the regional innovation systems in which their subsidiaries are located. In parallel, these subsidiaries also use this institutional and interorganizational context in order to increase their own innovativeness and to improve their position within the multinational corporation (Kristensen and Zeitlin 2004). This involves, above all, a regional environment that offers strategic advantages for companies, for example, due to specific knowledge of regional suppliers, customers, or competitors (Reger 1997; Cantwell and Piscitello 2002; Edler et al. 2003). As already pointed out, these subsidiaries not only rely on their own regional environment but also manage the access to other regional environments within or outside the respective national innovation system (Meyer-Krahmer 2003). However, regional innovation potentials also play a crucial role for the company-wide distribution of responsibilities and resources, because the corporate headquarter has to evaluate the comparative advantages of their operating units. In a knowledge-based society this refers also to the innovativeness of the different national units.

5.2.5 Conclusions

It can be concluded from this discussion that regional capabilities are based essentially on the utilization and advancement of context-specific, tacit knowledge in regional, institutionally stabilized communication and cooperation networks. An efficient regional infrastructure and innovative suppliers, buyers, customers, and competitors can be a considerable advantage in company-wide exchange processes and in struggles for the company-wide distribution of resources and responsibilities. This might imply that the innovativeness of MNEs also depends on the innovation-supporting conditions at the locations of their subsidiaries, while – vice versa – the capabilities of regional innovation systems depend on the successful embedding of MNEs.

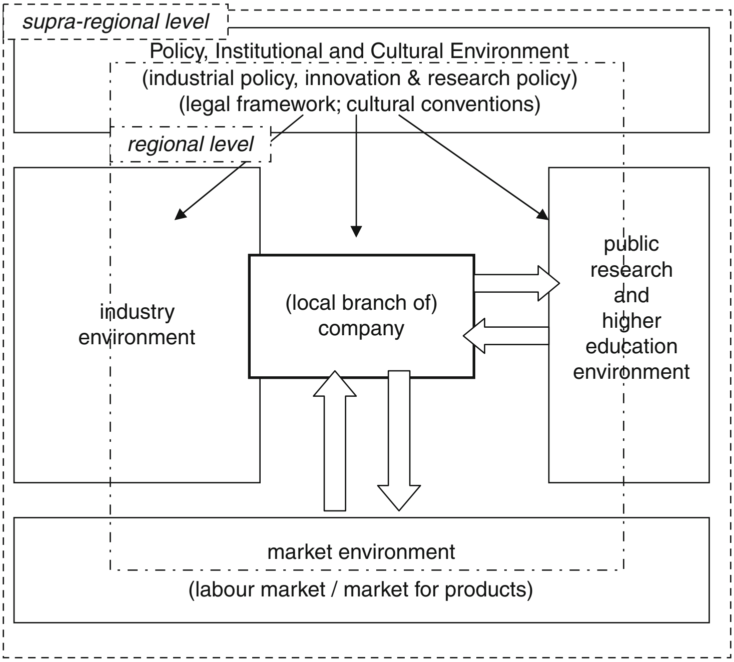

Fig. 5.1 Schematic illustration of a firm's embeddedness in its regional and supra-regional environment. Source: Hemer et al. (2007)

Figure 5.1 summarizes this understanding of territorial embeddedness. It builds on the modern understanding of the innovation process which assigns crucial importance to interaction and implies that networking and collaboration are central to a firm's efforts to maintain innovative competitiveness. It is also based on the recognition that linkages are by no means homogeneous and can be both regional and supra-regional. While not denying the importance of intraorganizational linkages, the framework depicted in Fig. 5.1 aims to assess the relative importance of regionalized external linkages that embed a firm into its different regional and inter-regional environments.

Based on the discussion of the possible impacts of the regional factor endowment on innovative activities of MNEs, and also bearing the footloose character of MNEs in mind, we will empirically test in the following section whether MNEs are footloose in the sense that their locations can be found everywhere irrespective of the quality of their regional environments, or whether these firms show a propensity to locate at regions which reveal certain innovative characteristics. This research focus is in accordance with Cantwell and Piscitello (2002, p. 71), who argue that "…there is still only quite a scant existing empirical research on multinational location at this subnational level."

Two confronting theses will guide our empirical analyses:

1. Due to the need to get access to strategic relevant knowledge resources and to exploit the advantages of innovative locations (cf. Fig. 5.1), the number of MNEs is significantly higher in regions which are characterized by a well-above-average endowment with innovation-relevant parameters.
2. Due to their global sourcing of knowledge and their independence from supportive regional or national environments, MNEs are footloose in the sense that their locations do not significantly correspond with the regional endowment of innovation-relevant parameters.

Our empirical analysis will be based on a cluster analysis for 215 European regions using Eurostat regional statistical data. Since data and indicator availability are limited for a European cross-regional analysis, our approach cannot go as deep as to identify causes and effects of the location decisions of MNEs. It can, of course, be argued that MNEs locate where other MNEs already have their location (signaling favorable location conditions), and a regional concentration of MNEs can therefore be expected. But, on the contrary, not all MNEs must follow the same locational trajectory, because they want to minimize disclosures risks and spillover effects, e.g., through a common labor market, by not being too closely located in the neighborhood of a competitor (Narula and Santangelo 2009, p. 401). MNEs might also differ in their strategic goals and thus their locational preferences. However, if it can be shown statistically for a broad set of regions that MNEs tend to favor certain types of regions (e.g., agglomerations or metropolitan areas), the conclusion can be drawn that their factor endowment is strongly attractive for MNEs in order to exploit the available skills and competences by a closer regional embeddedness and the integration into regional network relationships.

5.3 Regional Embeddedness and the Presence and Absence of MNEs in European Regions

5.3.1 Methodological Approach

In order to get an insight into the location pattern of MNEs at the European level and the characteristics of the regions in which these MNEs are located, we pursue a two-step approach. The first step aims to characterize European regions according to environmental aspects as depicted in Fig. 5.1, while the second step matches the findings of this characterization with the location of MNE headquarters. As a result, regional specificities and MNE locations are commonly considered in order to draw conclusions concerning locational characteristics of regions and their “attractiveness” for MNEs according to the two confronting theses formulated previously. So, the first step aims to group and characterize European regions with respect to selected variables which were chosen according to the schematic illustration of a firm’s

Table 5.1 Indicators and variables for a firm's regional embeddedness

Environments	Variable	Indicator for
Industry environment	Location quotient for the manufacturing sector[a]	Regional concentration in manufacturing with respect to the national level
	Employment in knowledge-intensive services (% of total employment)	Importance of the knowledge-intensive business services sector (KIBS) in the regional economy
	Employment in high and medium high-tech manufacturing (% of total employment)	Importance of the medium and high-technology manufacturing sector in the regional economy
	Number of patent applications at the European Patent Office (EPO) (per million labor force)	Innovativeness of regional economy
Public research and higher education environment	R&D personnel in the Government sector (% of total employment)	Potential in public research and higher education
	R&D personnel in the higher education sector (% of total employment)	
	Government expenditures on R&D GOVERD (% of GDP)	
	Higher education expenditures on R&D HERD (% of GDP)	
Market environment (labor market/ market for products)	Employment rate (%)	Labor market
	People participating in lifelong learning (% of total population)	Labor market/human capital
	Gross domestic product (GDP)/capita	Market characteristic: purchasing power
	Average annual growth rate of GDP 1995–2003	Development of regional wealth
MNEs	Absolute total number of large firms' headquarters	Presence and decision units of multinational enterprises

[a]The location quotient has been calculated as relation of regional employment in the manufacturing sectors compared to the respective national value. Location quotients higher than 1 indicate an overproportional share of regional employment in manufacturing compared to the national level of this region. A location quotient smaller than 1 indicates an underproportional share respectively

embeddedness in its regional environment (cf. Fig. 5.1). This first step of the analysis contains the variables and indicators as displayed in Table 5.1. It could be argued that this set of variables implies a bias towards regional characteristics, but in case the analyses show no relationship between regional characteristics and the location of MNEs, then this would be an additional strong support for thesis 2.

As summarized in Fig. 5.1, the regional embeddedness of a firm or a branch location of a MNE depends on a set of regional characteristics which can be grouped into three dimensions: the industry environment, the market environment, and the public research and higher education environment. Table 5.1 shows that a balanced set of variables for the industrial environment, the public research, and higher education environment and the market environment is used for the analysis of regional specificities in Europe. However, Fig. 5.1 additionally refers to the political, institutional, and cultural environment, aspects that are of high importance in analyzing innovation activities and specific (regional) innovation patterns. But, so far, it has not been possible to grasp these characteristics with the help of quantitative variables available for European regions, so that they cannot be integrated in the following analysis. Generally, only such variables which are suitable to represent the three environments (industry, public research and higher education and market) and, additionally, where data availability was sufficiently high have been included in our analyses. The rationales behind the selection can be found in the last column of Table 5.1 where we explain the indicators presented by the selected variables. For the second step of the analysis, we added a variable which represents the existence of MNEs in a region.

For allowing comparability across European regions, most of the data have been extracted from the Eurostat regional database. The central variable, however, refers to MNEs, which could not be extracted from the Eurostat database. According to our knowledge, only a few databases or statistics indicating research locations of MNEs at the subnational level exist. We derived the regional location of the headquarters of 700 enterprises with the highest R&D spending in Europe from an analysis of the 2005 EU Industrial R&D Investment Scoreboard (European Commission 2005). The headquarters of the enterprises were identified in a first step and then enumerated and assigned to the respective region. With this proxy variable we capture the headquarter function of research-intensive MNEs by the absolute number of MNE headquarters per region.

The preferred regional level to be used for our statistical analysis was NUTS 2[1]; however, this detailed level led to the two following principal problems: First, in some – generally smaller – countries, NUTS 2 level regional units do not exist or are identical with the superior NUTS 1 and/or NUTS 0 levels. So, generally, the highest possible level of analysis has been chosen.[2] Second, in some cases, innovation data are not available at the NUTS 2 level. Thus, the NUTS 1 level has been chosen instead. This is the case for the United Kingdom and Belgium. Generally, data availability proved to be difficult, since even singular data gaps lead to a removal of the respective region from the performed cluster analysis.

Since we aimed at a highest possible representation of regional variability within Europe, we chose the following approach: First of all, the year 2003 has been selected as reference year since timeliness combined with data availability proved to be the best in this year. We checked data for each variable and in cases of data gaps we used the "nearest time neighbor" method, i.e., attributed available data from the nearest possible

[1] Nomenclature des unités territoriales statistiques, the nomenclature of territorial units for statistics. Cf. http://ec.europa.eu/comm/eurostat/ramon/nuts/home_regions_en.html (01.04.2008).

[2] Denmark, Luxemburg, Cyprus, Lithuania, Estonia, Latvia, Slovenia and Malta have been analyzed on the NUTS 0 (country) level.

year to 2003. In the case of two possible data points, e.g., from 2002 to 2004, we chose the 2002 data with the assumption that this has a greater influence on our target year.

First, we attempted to gather further information about average characteristics of European regions in relation with the respective presence of MNEs. In order to identify regional types across Europe according to regional similarities with respect to the chosen indicator set and to draw conclusions with regard to the presence of MNEs in such regions, we chose the method of cluster analysis (Backhaus et al. 2006, pp. 511ff.). For this purpose, we calculated a *k*-means cluster analysis with three clusters with altogether 215 European regions. Second, we performed a discriminant analysis in order to investigate which variables contribute significantly to the discrimination between the clusters. As indicated above, we excluded the MNE variable from these analyses and reintegrated it in the second step, i.e., a matching of regional types with the presence of MNE headquarters in the form of a graphical analysis. By this latter approach, the results of the cluster analysis are presented in a map with two attributes: the clusters and the absolute number of MNEs. In order to validate our results finally, we used a Kruskal–Wallis test in order to validate differences in the absolute number of MNEs between the clusters. All statistical calculations have been performed with SPSS 11.0.

5.3.2 Clustering European Regions

Table 5.2 shows the results of the *k*-means cluster analysis. It took altogether five iterations of the cluster centers to arrive at the final results. The cluster centroids allow us to characterize the three selected clusters and to derive specificities in these types that distinguish them from the other two regional types.

As mentioned above, the cluster analysis is based on 215 European regions. These regions have been assigned to the three clusters. The first cluster in which 124 regions are summarized has a strong industrial base (Sect. 5.3.2.1), whereas the second cluster, which subsumes 72 regions, rather represents regions that are lagging behind as regards economic development and regional innovative capacity (Sect. 5.3.2.2). The third cluster includes those 19 regions, clearly showing signs of metropolitan areas and regional leadership (Sect. 5.3.2.3). Additionally, it seems important to mention that we can find 87 regions in which one or more MNEs (MNE headquarters) are present and 128 regions without the presence of MNEs. Although regions are not equally distributed between the three clusters, the distribution seems to be plausible, given the fact that altogether 128 regions do not host an MNE headquarter at all and that one would expect that leading regions are not as common as others.

We will now briefly describe and analyze the results obtained from the cluster analysis according to the three theoretically derived environments, which are decisive for a firm's regional embeddedness (cf. Fig. 5.1). The values represent the cluster centers, obtained from the cluster analysis and are complemented by the mean value across all regions (cf. Table 5.2). Drawing on these results we reflect the clusters' specificities as regards their attractiveness for MNE location at the end of each cluster description.

Table 5.2 Results of the cluster analysis – as cluster-centroids and means

Variables	Cluster 1	2	3	Means
Location quotient for the industrial sectors (2003)	1.06	0.97	0.82	1.01
% of employment in total knowledge-intensive services, 2003	32.12	23.42	43.22	30.19
% of employment in high-tech and medium high-tech manufacturing, 2003	7.49	4.77	6.26	6.51
Total number of patent applications at the EPO, per million people in labor force, 2003	161.71	10.96	265.13	122.10
Employment rate in %, 2003	52.88	47.28	57.44	51.41
R&D personnel by sectors of performance as percentage of total employment, government sector, 2003	0.16	0.17	0.29	0.17
R&D personnel by sectors of performance as percentage of total employment, higher education sector, 2003	0.63	0.57	0.85	0.62
People participating in lifelong learning as % of total population, 2003	0.09	0.05	0.13	0.08
GDP per capita, 2003	23,702.79	9,645.06	39,038.62	20,350.34
Average annual growth rate of GDP, 1995–2003	4.14	7.66	4.83	5.38
GOVERD (total intramural R&D expenditure in % of GDP, government sector) 2003	0.20	0.13	0.26	0.18
HERD (total intramural R&D expenditure in % of GDP, higher education sector), 2003	0.41	0.23	0.50	0.36

Source: own calculations

5.3.2.1 Industrial Regions

Cluster 1 in Table 5.2 summarizes the characteristics of the regions which reveal regional innovation potentials based on a strong industrial base. With altogether 124 regions, which belong to this group, cluster 1 is the largest in our analysis. Among those regions are Tuscany, Umbria, Lisbon, Berlin, Molise, Liguria, Pais Vasco, Lower Austria, Örve Norrland, Lower Normandy, Leipzig, Dresden, Madrid and Cantabria, just to mention some examples.

The economic environment can be described by a strong industrial base, which is indicated by a location quotient of 1.06 and a high percentage of employment in high and medium high-tech manufacturing of 7.49% (average: 6.51%). The value of the latter indicates not only a strong presence of enterprises in industrial sectors but also a clear high-tech orientation of those enterprises. This corresponds with a relatively high number of patent applications. Altogether, 161.71 patent applications are filed per million of people in labor force at the European Patent Office (EPO). The presence of knowledge-intensive business services (KIBS) is rather on average with 32.12% of the employees working in those industry sectors.

The market environment of this cluster is slightly of average, especially with a look on the labor market. The employment rate reaches 53%, and 9% of the total population participate in lifelong learning. GPD per capita builds up to EUR 23,702 per year, slightly above the average for all regions of EUR 20,350. These regions additionally reveal a below-average annual growth rate of 4.14% (European average 5.38%). In combination, this indicates a slightly less dynamic growth pattern compared to the European average.

The public research and higher education environment is characterized by average figures. HERD reaches a relatively high 0.41% and GOVERD 0.20% (as compared to 0.36 and 0.18%, respectively). Of the total employment, 0.63% is R&D personnel in the higher education sector, which is close to the European average of 0.62%, and 0.16% is R&D personnel in the government sector, which is the lowest average value in all clusters. From this it can be concluded that the regions reveal a high density of higher education institutions (universities), which are also very active in performing R&D, but government engagement in R&D is very low which is also mirrored by the small R&D employment rate in the government sector.

We conclude from these results that these regions could be attractive for certain MNEs, especially those which would like to engage in a strong industrial base, and which need respective networks. Nevertheless, this explicit orientation towards industry sectors might give a hint that despite a strong industrial base the regions have difficulties in both managing structural change and keeping their positions of industrial leadership.

5.3.2.2 Lagging Regions

Cluster 2 in Table 5.2 summarizes the characteristics of the regions which are lagging behind not only regarding the overall regional endowment with innovation favorable factors but also regarding economic aspects. It comprises 72 regions altogether. Among those regions are many regions from Poland, Hungary, Slovakia, Slovenia, Czech Republic as well as Lithuania, Estonia, and Latvia. In addition, many regions from south and south Western Europe are found.

The industrial environment is very weak. The data reveal neither a concentration of industrial sectors (location quotient is smaller than 1) nor a specialization in high-value industries, such as employment in high-tech manufacturing or KIBS. Likewise, the market environment is also weak. These regions have a very low employment rate of below 50% and only a very little percentage of the population (5%) participates in lifelong learning. GDP per capita is very low with an average of EUR 9,645 (average value EUR 20,350). Since GDP per capita is so low that these regions reveal, however not surprisingly, high annual GDP growth rates of 7.82%, which indicate that they are in a catching-up process.

The public research and higher education environment indicators are characterized by very low percentage shares. HERD reaches 0.24% and GOVERD reaches 0.15%. Of the total employment, 0.60% is R&D personnel in the higher education sector. Although this value is lower than in the other clusters, education efforts and investment in human capital are important for future attractiveness, and 0.19% R&D

personnel can be found in the government sector. Given these characteristics, we conclude that these regions seem to be of lesser interest for territorial integration for MNEs. As a result, we would expect the presence of MNEs to be very low.

5.3.2.3 Regional Leaders

Cluster 3 in Table 5.2 summarizes the characteristics of those regions which reveal good regional endowment with innovation-relevant parameters. With our approach, we were able to identify altogether 19 regions in Europe, for which this holds true. The following regions belong to this group: Stockholm, Denmark, Vienna, region of Southern Finland, Utrecht, Groningen, Stuttgart, Province of Bolzano-Bozen, Île de France, Darmstadt, Bremen, North-Holland, Hamburg, Upper Bavaria, Luxembourg, and the region of Brussels and London.

The industrial environment is characterized by a strong presence of KIBS. On average, altogether 43.2% of the working force is employed in KIBS in these regions (European average: 30.19%). When compared to the cluster centers of the other two clusters this is an exceptionally high percentage. On the other hand, the average location quotient for industry of 0.82 indicates that manufacturing or traditional industrial sectors are slightly underrepresented. Nevertheless, the average percentage of employment in high and medium high-tech manufacturing is 6.26%, which is rather high. Additionally, with 265.13 patent applications filed at the EPO per million people in labor force, regions in this cluster are performing extremely well, when compared to the cluster centers of the other clusters.

The regions in this cluster are characterized by a very strong market environment, which comprises indicators of economic wealth as well as good labor market indicators. GDP per capita reaches EUR 39,038. The average annual growth rate of the GDP (in million Euro) between 1995 and 2003 is 4.83%, which is slightly below the European average of 5.4%, but higher than that of cluster 1. Since the initial starting point of GDP is already high, growth rates cannot be expected to be as high as when the initial starting point of GDP is low (as is the case with cluster 2, for example). Concerning the labor market, our cluster analysis reveals that the employment rate is 57.44%, the highest among the three clusters (European average: 51.41%) and so is the percentage of people participating in lifelong learning, which stands for the qualification of the work force.

The public research and higher education environment is also comparatively strong. Expenditures on public research and higher education are higher than in other clusters. HERD (expenditures in % of GDP in the higher education sector) reaches 0.50% and GOVERD (expenditures in % of GDP in the government sector) reaches 0.26% respectively. Of the total employment, 0.85% are R&D personnel in the higher education sector and 0.29% are R&D personnel in the government sector. It can be concluded that those regions which reveal a high density of higher education institutions (universities) are also very active in performing R&D. This makes them equally attractive for students and also for enterprises which seek a highly qualified workforce. We would expect that the regions which belong to cluster 3 are able to attract MNEs due to their favorable regional environment, such as a high presence of KIBS, a high patent activity, economic wealth, and a high HERD and GOVERD which indicates complementary regional assets regarding innovation potential. MNEs have many possibilities to mingle with regional actors, which are amply present.

To avoid misinterpretations, we investigated with the help of discriminant analysis as to which variables contribute significantly to the discrimination between the clusters. Due to missings in our data we were however only able to include 162 European regions (or 75.3%) in our discriminant analysis. In 53 cases, at least one discriminant variable is missing.[3] For obtaining information on the relative importance or contribution of each variable towards the discrimination between the clusters, we have calculated Wilks' lambda. The Wilks' lambda significance test checks the hypothesis that the means of the functions listed are equal across groups, Wilks' lambda being the proportion of the total variance in the discriminant scores not explained by differences among the groups:

$$\Lambda = \frac{1}{1+\gamma} = \frac{\text{unexplained variance}}{\text{total variance}}.$$

A significance value less than 0.05 indicates that the group means differ, and therefore the function is a significant discriminator. Additionally, Wilks' lambda is an inverse measure of quality; small values indicate a stronger separating power of the discriminant function.

As we can see from the results presented in Table 5.3, only GOVERED does not contribute significantly to the separation between the clusters at a 5% level. GDP per capita separates best with a Wilks' lambda of 0.184, followed by GDP growth, with a Wilks' lambda of 0.542 and the KIBS variable, which reveals a Wilks' lambda of 0.569. The canonical correlation of the first discriminant function obtained is very good, with a value of 0.917 and an eigenvalue of 5.296.

Interestingly, two determinants of the market environment seem to dominate the cluster analyses followed by the KIBS variable, which determines the industry environment and includes aspects of knowledge generation and points towards a highly skilled work force. This means that particularly the regional wealth characteristics – in terms of GDP per capita 2003 – and also its evolution between 1995 and 2003 and the share of the regional workforce being employed in KIBS are of outstanding importance in building the types of European regions. Matching this result with the clustering results in Table 5.2, it becomes clear that indeed type 3 regions have by far the highest average GDP/capita (EUR 39,038.6) which is more than four times as high as that of type 2 regions (EUR 9,645.1). On the other hand, GDP growth in type 2 regions exceeds that of type 3 and also of type 1 regions, being more than

[3]The *k*-means cluster analysis could manage this data gap problem by using "exclude cases pairwise" as a base for the calculation, meaning that all cases with nonmissing data are included for the variables in question, independently from missing data for other variables, i.e., through this option, all available nonmissing data are integrated into the analysis.

Table 5.3 Wilks' lambda and related significance

Variables	Wilks-lambda	*F*	d*f*1	d*f*2	Significance
Location quotient for the industrial sectors (2003)	0.858	13.104	2	159	0.000
% of employment in total knowledge-intensive services, 2003	0.569	60.227	2	159	0.000
% of employment in high-tech and medium high-tech manufacturing, 2003	0.911	7.760	2	159	0.001
Total number of patent applications at the EPO, per Million people in labor force, 2003	0.837	15.442	2	159	0.000
Employment rate in %, 2003	0.661	40.836	2	159	0.000
R&D personnel by sectors of performance as percentage of total employment, government sector, 2003	0.954	3.823	2	159	0.024
R&D personnel by sectors of performance as percentage of total employment, higher education sector, 2003	0.949	4.256	2	159	0.016
People participating in lifelong learning as % of total population, 2003	0.845	14.573	2	159	0.000
GDP per capita, 2003	0.184	353.731	2	159	0.000
Average annual growth rate of GDP, 1995–2003	0.542	67.287	2	159	0.000
GOVERD (total intramural R&D expenditure in % of GDP, government sector) 2003	0.970	2.423	2	159	0.092
HERD (total intramural R&D expenditure in % of GDP, higher education sector), 2003	0.848	14.204	2	159	0.000

Source: own calculations

1.5 times as high as that of the third type cluster. This inverse relationship points towards the fact that leverage effects in regions with a high GDP must be much higher to achieve similar growth rates than regions that are on a lower level. Looking finally at the KIBS variable, Table 5.2 shows intercluster differences between the average shares of employment in knowledge-intensive services, particularly between clusters 2 (23.42%) and 3 (43.22%) with cluster 1 regions in between them.

On the other side of the spectrum, the variables representing the public research environment (cf. Fig. 5.1) prove to be of less importance in determining the clusters of European regions with GOVERD 2003 (total intramural R&D expenditure in the government sector, share of GDP) being not significant at the 5% level (cf. Table 5.3). This indicates that the cluster building does not seem to be significantly determined by the GOVERD variable: Mean values are between 0.13% (type 2) and 0.26% (type 3). These findings allow the conclusion that public characteristics, particularly

R&D expenses, show comparatively smaller variations between the European regions and are thus weaker discriminators for regional typologies than industrial and market environment characteristics.

5.3.3 Matching of the Regional Clusters with the Location of Multinational Enterprises in Europe

Figure 5.2 shows the result of the second step of our analysis, the matching of the cluster typology with the location of MNE headquarters across Europe. The map has been produced using ArcGIS 9, choosing a central European-centered projection. It presents the regions of the three types in different grey shades and additionally the number of MNEs as circles that differ in size according to the number of MNE locations.

Figure 5.2 reveals a distinct pattern of regional profiles within Europe: In the south and east of the European Union, regions of the lagging type to which belong the New Member States (the Baltic States, Poland, the Czech Republic, Hungary, Slovenia, Slovakia, Cyprus, the main part of Greece (except Sterea Ellada), Malta, the south of Italy, Portugal except Lisboa, and southern Spain) can be found. Central and northern Europe are highly characterized by industrial regions (type 1) which comprise the main parts of Finland, Sweden, the United Kingdom, Germany, Belgium, the Netherlands, France, northern Spain, northern Italy and Austria. The two Irish regions are made up of types 1 and 3. Type 3 regions are mainly capital or metropolitan regions, as well as Denmark and Luxembourg. Looking closer at the distribution of MNE headquarters, Fig. 5.2 also makes clear that regions with the highest number of MNEs can be found in central and northern Europe. Regions with more than 15 MNEs show a V-shaped distribution within Europe, with the main locations in Finland, Sweden, Denmark, Germany, Austria, the Benelux States, via Paris to Great Britain and Ireland.

Having a closer look at both types of variables considered, it becomes evident that the majority of MNEs is located in regions of types 1 and 3, i.e., in industrial regions and regional leaders, whereby regional leaders clearly host the highest average number of MNEs (15.7), followed by industrial regions with a mean value of three MNEs. Concerning the lagging regions, only few of them (Praha, Andalucia, Attiki, Közép-Magyarország, Mazowieckie and Slovenia) are shown as location of MNEs.

As Table 5.4 depicts, the three identified clusters display strong differences with respect to the number of MNE headquarters located within their territory. Cluster type 3 is the clear "favorite" region type for MNEs to locate their headquarters: only four of the 19 regions of this type do not have any MNEs (Bremen, Åland, the Provincia Autonoma Bolzano-Bozen and Groningen), with the other 15 regions displaying three or more MNE headquarters, and six of them being the location of more than 20 MNEs (Upper Bavaria: 21 MNEs, Denmark: 31 MNEs, Île de France: 65 MNEs, Stockholm: 33 MNEs, London: 50 MNEs and Etelä-Suomi: 36 MNEs). This leads to the observation that both median and mean values are highest among the regional cluster types; however, the strong difference between these values points at individual regions with high numbers of MNE headquarters. Of the MNEs in our sample, 44% are located in regions of type 3.

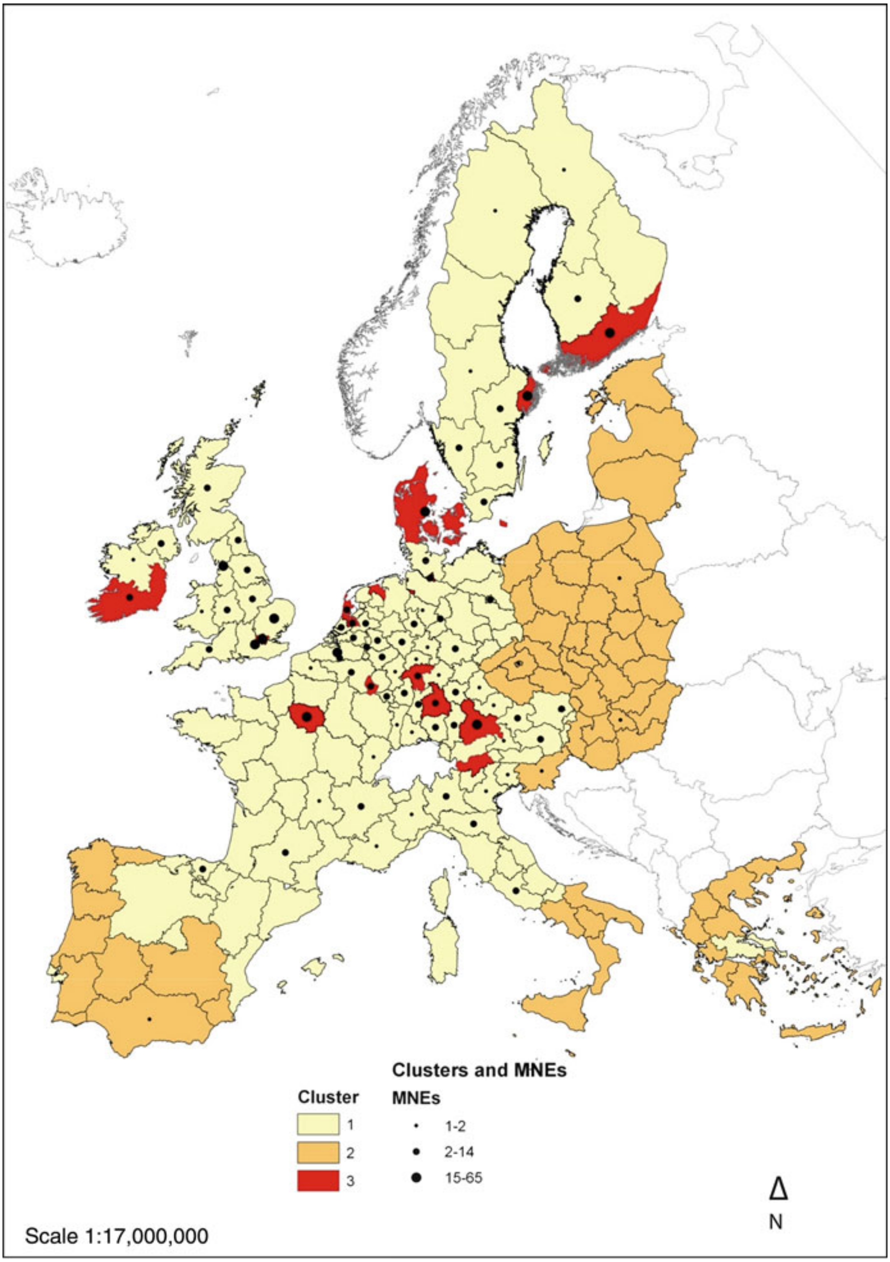

Fig. 5.2 Regional clusters and location of MNE headquarters in Europe. Source: own draft based on Eurostat data

Table 5.4 MNE characteristics of the three cluster types

	MNE characteristics				
Cluster	Minimum	Maximum	Mean value	Median	Sum
1 (industrial regions)	0	60	2.98	1.00	369
2 (lagging regions)	0	2	0.15	0.00	11
3 (regional leaders)	0	65	15.74	7.00	299

Source: own calculations

Type 1 regions to which 124 European regions belong, according to our typology, host 54% of the sample MNEs. Nearly half of these regions (58) do not show any MNE, with two of them having more than 20 MNE headquarters (Eastern region UK: 50 MNEs and South East UK: 60 MNEs). This leads to median and mean values strongly below those of the third cluster regions. Fifty-one industrial regions have between one and five MNEs, indicating that high MNE numbers are rather an exception. However, a considerable number of European R&D-intensive large companies seem to appreciate industrial regions as location for their headquarters.

Finally, lagging regions – based on our analysis, 72 European regions belong to this regional type – have 11 MNEs altogether. As already indicated above, the large majority of those regions do not host any MNE headquarter; one region has one (Andalucia) and five regions have two MNEs on their territory (Praha, Attiki, Közép-Magyarország, Mazowieckie and Slovenia). This produces a median of 0 and a comparatively low mean value of 0.15 MNEs (cf. Table 5.4). Lagging regions must thus be considered as comparatively unattractive locations for MNEs.

Differences in the absolute number of MNEs between the three regional types are highly significant, as the mean ranks already indicate – cluster 3 has by far the highest mean rank through integrating the smallest number of regions, opposed to cluster 2 with by far the smallest mean rank – as a Kruskal–Wallis test verifies (cf. Table 5.5).[4] As Table 5.5 shows, the test calculates a chi-square of 60.2. Based on two degrees of freedom, the p-value (asymptotic significance) is equal to 0.000. There is consequently strong evidence to reject the null hypothesis that the MNE distribution is equal in the three clusters identified. This leads to the following two main conclusions: (1) First of all, the three clusters differ indeed in a significant manner concerning the number of MNEs located in their regions, a result which does not seem to be astonishing after analyzing Table 5.4, but (2) when keeping in mind that the three cluster types have been built according to regional characteristics with respect to the industrial, market, and public research and education environment (as shown in Fig. 5.1), it is interesting to see that MNEs are not equally distributed across the clusters. On the contrary, the three clusters which show distinct regional characteristics also differ with respect to the number of MNEs. The attractiveness of regions as locations for MNEs proves to be, to a certain extent, congruent to regional market, industrial and public research patterns. MNEs seem to be most strongly

[4]As the normality assumption for performing an analysis of variance is not met, we chose the nonparametric Kruskal–Wallis test which uses the ranks of the data.

Table 5.5 Comparison of MNE distribution in clusters: Kruskal–Wallis test

Absolute number of MNEs in cluster…	*N*	Mean rank
Ranks		
1 (industrial regions)	124	119.82
2 (lagging regions)	72	71.55
3 (regional leaders)	19	168.97
Total	215	
Statistics	Absolute number of MNEs	
Kruskal–Wallis test		
Chi-square	60.224	
Degrees of freedom	2	
Asymptotic significance	0.000	

Source: own calculations

embedded in regions with a high-tech and particularly knowledge orientation of their industries, as well as knowledge and qualification orientation of their inhabitants. Those regions are consequently offering a larger embeddedness potential for MNEs. However, there is also a certain share of MNEs that prefer industrial regions as location for their headquarters.

These results might be an indication of the fact that MNEs and their subsidiaries fulfil different functions in the way that some are related to production and postproduction activities (downstream), while other focus on preproduction activities (upstream) such as research, development and headquarter functions (Defever 2006, p. 660). For upstream-oriented MNEs, a high-tech and knowledge orientation of their locations is an important prerequisite, and an above-average orientation towards manufacturing industries seems to be of importance for downstream-oriented MNEs.

5.4 Conclusions

Based on two confronting theses it was the objective of this paper to analyze whether MNEs do not show a propensity to locate at certain locations – and are thus footloose in the sense that the quality of their regional environments does not matter, or whether these firms need to exploit the advantages of innovative locations and favor significantly certain regions with a well-above-average endowment of innovation-relevant characteristics. These theses were tested by identifying three types of European regions by cluster analysis which reveal different characteristics, i.e., industrial regions, lagging regions, and regional leaders, and by statistically relating the location pattern of MNEs in Europe to these three regional clusters. The results of this empirical analysis lead to the following conclusions:

- Generally, the results show that regions with an above-average endowment of factors related to knowledge, research, and qualification host above-average shares of MNE headquarters in Europe. MNEs are not indifferent towards their regional environments. Especially regions with a high innovation potential – particularly market and knowledge-related attributes – are attractive locations for most MNEs.

- Research-oriented MNEs, as those of our sample which has been produced on the basis of the headquarter location of the most R&D-intensive large companies in Europe, tend to favor locations with a strong and efficient knowledge-oriented environment. It is rather knowledge, research, and high technology that characterize regions of this type: below-average concentration in (traditional) industries, but high employment in high- and medium-high-tech sectors, high importance of KIBS that are attributed a pertinent role in the generation, diffusion, and brokerage of knowledge, both aspects that lead to a strong patent performance. The market environment of these regions is also very strong, measured in terms of employment rate, skills, and qualifications of the work force. Finally, public research is also strong in these regions. Regions of this type seem to provide very good preconditions for MNEs to locate their headquarters.
- However, industrial regions also seem to be attractive for (a part of) MNEs. Regions of this type show a strong industrial base with a high and above-average concentration of manufacturing activities and high employment shares in high and medium high-tech manufacturing sectors. This leads to the conclusion that MNEs located here can be assumed to rely their activities on a strong manufacturing base of their environments. Regions of this type also have high numbers of patent applications, but do not reach leading regions in terms of inventions filed at the EPO. Both the market environment and public research in these regions are good, but not outstanding in comparison to the European leading regions.
- Although our data do not allow to make a distinction between different functions that the MNEs fulfil at their location (besides the fact that they are classified as research intensive), this regional location pattern seems to coincide with results from other studies in the way that regions displaying a strong industrial base are attractive for downstream activities (production and post-production), while knowledge-oriented regions are favored by MNEs with upstream functions such as R&D and headquarter activities (Defever 2006). In this respect, our sample is biased in the sense that most of the R&D-intensive classified MNEs show a high propensity to locate in the regional leaders' cluster.
- A policy-oriented conclusion derived from our theoretically deduced model would point to the importance of creating an attractive environment in order to maintain and achieve a high embeddedness potential. Much attention should be paid towards an efficient economic environment as well as a focus towards knowledge-related industries, as shown by the discriminant analysis.

Although we find evidence that MNEs are somehow regionally embedded, we cannot conclude that they are not footloose. On the one hand, MNEs favor certain types of regions, but, on the other, they have of course the flexibility to move to other locations which offer similar or even better conditions for their economic activities. The possibility of exploiting advantages of regional interconnectedness, i.e., to link and combine different regional advantages through global networks or to shift research and production activities within the MNE to those locations which offer specific benefits for specific project needs, is a special characteristic of MNEs (Bunnell and Coe 2001; Saliola and Zanfei 2009; Ito and Wakasugi 2007). We can finally conclude that MNEs are regionally embedded and disembedded at the same time, so that the question whether they are footloose or not can be answered in both directions, depending on either a regional or a company perspective.

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Chapter 6
Competencies for the "Technological Europe" of Tomorrow: A New Model and an Emerging Concept of Interorganizational Competence

Pierre-Yves Sanséau

6.1 Introduction

The literature is replete with empirical studies focusing on competency management – in its many forms and interpretations. With a broad scope and constantly emerging new concepts, competency management is today characterized by its multitude of dimensions and unique features. The literature currently puts forward definitions and descriptions of several types of competences: individual, organizational, strategic, collective, environmental, and territorial.[1]

This chapter aims to further our knowledge of competency management by looking at a new – new in the sense that our field research has enabled us to identify and define it – type of competence: interorganizational competence.

The need for a new concept arose from our research into the little-known links between two aspects of competence, collective competence and environmental competence. The idea took form during research conducted for the E.U. Matri project to identify and forecast the competencies of the future in the high-tech industries.

[1] Here, we will use Dietrich's (2008) definitions of the different types of competences: (1) Individual competence: knowledge, skills, and behaviors acquired by individuals in the course of their work. (2) Collective competence: the result of synergies between individuals' capacities, and effective team management. (3) Organizational competence: the organization's capacity to use the available resources to optimize operations and create value. (4) Strategic competence: rare competencies that are difficult to imitate or reproduce and that give the company a decisive advantage. (5) Environmental competence: competencies outside of the company held by partners (suppliers, customers, or other partners); furthermore, territorial competence is specific to a geographical area (such as clusters, for instance).

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The research highlighted how the links between collective and environmental competencies could provide insight into the role of environmental factors in the collective aspect of the competencies of today and tomorrow.

In this chapter, we will analyze this link based on an empirical study carried out at an international semiconductor company. We will also explain how we came to identify a new type of competence: interorganizational competence. We will begin by reviewing current ideas about collective competence and environmental competence. Subsequently, we will outline the topic of our research, describe the context in which it was carried out, and explain the methodology used. We will then present the findings of our research, followed by analysis and discussion of a model of collective competence that includes an external – or, more accurately – interorganizational – dimension and the emergence of a new concept: interorganizational competence.

6.2 Collective Competence and Environmental Competence: Limitations of the Current Thinking

Around 25 years of professional practice and research on the topic of competency management have enabled practitioners and researchers to explore a vast subject area whose scope and applications vary from one continent to another (with marked differences between Europe and North America) and from one academic discipline to another (Gilbert 2003; Bouteiller and Gilbert 2005; Defélix and Retour 2007; Sanséau 2007). In the literature, the concept of competence has been broken down into six types: individual, collective, organizational, strategic, environmental, and territorial. Our research focuses on two of these previously identified types of competence and how they are linked: collective competence and environmental competence. The management science literature does not offer any direct links between these two types of competence. We will begin by reviewing both of them briefly – their definitions, several models that have been used to describe them, and their limitations. We will then explain our research topic and the underlying concepts.

6.2.1 Competencies and Collective Competence: Issues and Links

"Collective competence" refers to the competencies that are used and developed in work groups (formal teams of employees, project teams, and other working groups). While the concept of collective competence is still nascent, the definitions that have been put forward thus far do reflect an approach that is becoming increasingly clear as researchers look more pointedly at its mechanisms – much like what was seen when the concept of individual competence first emerged (Klarsfeld 2000; Sanséau 2007). Collective competence refers to the interaction of people in workplace situations; to a combination of implicit individual competencies, knowledge, and skills; and to informal interaction driven by underlying affinities – all of which contribute to a group's "capacité répétée et reconnue" (recognized and repeated capacity) to coordinate their efforts toward a common outcome (Michaux 2003). Collective competence appears to be the most common response to complex situations (Chain and Moreau 1996).

Krohmer (2005) and Retour and Krohmer (2006) put forward a set of attributes of collective competence. The four main attributes are:

- A common frame of reference: The members of the group have to share a frame of reference based on having accomplished together real, profound, and productive work.
- A common language: This refers to the common vocabulary developed, reinforced, and used by the members of the group.
- A collective memory: According to Girod (1995), there are three types of collective memory: "declarative memory," "procedural memory," and "judgmental memory."
- A subjective commitment: The involvement of the group's members generates a capacity to create, to resolve problems, and to make decisions. This manifests itself in the form of group initiatives and the associated responsibilities.

Empirical research in management science has recently provided models and frameworks for analyzing the creation, development, and effects of collective competence (Dubois et al. 2003; Bataille 2001; Michaux 2003, 2005; Retour and Krohmer 2006). Here, we have chosen to use the framework put forward by Retour and Krohmer (2006), because of its operational nature and because it distinguishes between the creation and development of collective competence.

According to this framework, there are two types of factors that contribute to the creation and development of collective competence: individual factors and organizational factors.

Individual factors include:

- Individual competencies (assets)
- Affective interactions
- Informal relationships
- Cooperation

Organizational factors include:

- Team makeup
- Formal interactions
- Management style
- HR management drivers (recruitment, assessment, training, and compensation)

6.2.2 Environmental Competence: An Emerging Concept with Identifiable Limitations

Among the dimensions that have recently been identified in the competency management literature is environmental competence, which presents several unique features. Environmental competence deals with all of the factors within a company that have to do with competencies. Retour (2005) defined it as managing the competencies of the many stakeholders not under the direct control of the company, such as customers, vendors, institutional partners, or any other stakeholder that can influence the company. When defined in this way, environmental competence has not yet been researched thoroughly.

The concept of environmental competence refers to an approach to management that has, for the past 20 years or so, emerged from new kinds of organizations. Picq (2005) listed some of the many names that have been given to these new kinds of organizations, including network-based (Pache and Paraponaris 1993), multicellular (Landier 1987), virtual (Nohria and Berkley 1994), modular (Brilman 1995), entrepreneurial, and project-based.

According to Picq (2005), these new kinds of organizations are at the root of a set of common development and management principles, which underpin the emergence of environmental competence within organizations. These common development and management principles are:

- Cross-functionality: In other words, operations are transversal, with a strong emphasis on processes and the contribution made by all resources allocated to the process.
- Entrepreneurial projects: The organization, via its collective dimension, runs multiple projects, thus operating dynamically.
- Local self-organization: This refers to an optimized organization of work, bringing together many complementary skills through the constitution of teams, networks, or other forms of association in order to attain a specific objective within a given timeframe.
- Excellence: Distinctive individual or organizational knowledge is recognized, whether it is internal, external, or peripheral to the organization.
- Diversity: The blending of sometimes extremely varied backgrounds, professions, skill sets, cultures, and nationalities that must very quickly become operational to work toward a common goal.
- Time scale: These new kinds of organizations operate for the short term, in project mode; their end goal is not to build a stable long-term structure.
- Opportunity: An increasingly uncertain environment has given these new kinds of organizations a new driver for action, enabling them to assess and seize upon opportunities to take action and to innovate.
- Innovation: The new flexible, adaptive, transversal organizations are characterized by strong ties to innovation.

The concept of "co-opetition" suggested by Nalebuff and Brandenburger (1996) is a useful example of how these new organizations work. A blend of cooperation and competition, "co-opetition" also encompasses the duality between individual and collective interests. Alliances and various other forms of cooperation bring together development, competitiveness, and also risk, due to the unique nature of the relationship that has been established.

Managing environmental competence is one way to approach the issue of outsourcing or pooling resources; however, the current research does not give many indicators or much data on the impact that this "extended" competency management has on employees and communities (Defélix et al. 2007).

6.3 Our Research Topic and Context: Competencies for the "Technological Europe" of Tomorrow

6.3.1 *Matri: A Target for All of Europe*

We conducted our research under the E.U. Matri (Méthodologie d'Anticipation des Transformations Industrielles)[2] project, which aims to develop, validate, use, and disseminate a method for identifying the individual and collective competencies of the future in order to bolster E.U.-based high-tech companies' capacity to develop new products.

The research was initially based on the idea that, in order to develop and strengthen the competencies of researchers tasked with coming up with new products and services, you must first develop competencies founded on two capacities: First, the capacity to identify, access, and assimilate the knowledge of the local and global technological communities relative to new-product development; and, second, the capacity to build local or intracompany clusters, or, in other words, the technological communities of future.

The Matri project brings together partners from business and academia. Here, we will discuss only that research which focused on a global corporation operating on several continents. The company develops and manufactures new products in the field of microelectronics (semiconductors; analog and mixed-signal circuits).

6.3.2 *Identifying Competencies and the Links Between Them*

Given that the overall topic of the Matri project – the context for our research – is how to plan ahead for the competencies of tomorrow in high-tech companies, we focused our work on a more specific subtopic. The Matri project raised a number of questions stemming from how to identify types of competences through to practical ways to develop the competencies of tomorrow. We set out to answer the following questions: What are the relationships between collective competence and environmental competence in the emergence and development of tomorrow's competencies for the semiconductor industry? What is the role of "external" or interorganizational components in the collective competence of today and tomorrow for the semiconductor industry? Is there an "external" or interorganizational dimension to the development of collective competence in more general terms?

[2] Project funded by the European Commission, DG for Employment, Social Affairs and Equal Opportunities, Article 6 of the ESF and readaptation: www.matri-europe.com.

A Few Words About Our Methodology

Our field research included data gathering, which was carried out in several stages. First, we conducted a social network analysis (Cross and Parker 2004; Cross et al. 2006) to identify the key parties involved in informal project networks and their specific contributions to the new product development process. The social network analysis enabled us to pinpoint the degree to which formal organizational dimensions aligned with informal dimensions (such as communities of practice or networks); the key individual roles in innovation, namely knowledge brokers and central connectors (Cross and Prusak 2002); and, finally, the informal information-exchange channels both within the organization and outside (with the scientific R&D community, with customers and suppliers).[3]

After we identified the key individual roles (using our social network analysis), nine semi-directed interviews of 2 h each were conducted with people identified as knowledge brokers or central connectors. The size of our sample must be considered in light of our previous work to identify the key individual roles. A two-part interview guide was used. It contained questions to ascertain the competencies actually used in 2007–2008 and questions on the competencies that would need to be developed over the next 3–5 years. The purpose of the interviews was to understand current and future (3–5 years) assessments of changes in the business and its professions that would affect individual, collective, and environmental competences.

6.4 Findings: Collective Competence Is Changing in Content and Scope

An analysis of the interviews enabled us to identify the components of the collective competence of tomorrow and its links to the "environmental" dimension in the semiconductor industry.

First, we identified the competencies actually used in 2006–2007 within the project groups. This was made possible by interviewing the parties involved and analyzing their work situations and processes.[4] We then used the collective competence framework presented in Sect. 6.2.1 to pinpoint the collective competencies that were either emerging or in use. We identified three key aspects of the collective

[3] Assimakopoulos, D. 2007. Social Network Analysis (SNA) – Findings from the investigation of individual and collective competences in the semiconductor pilot experimentation. *Matri internal reports.*

[4] Chapelet, B., Donnadieu, M. and G. Michel. 2008. Recommandations pour le renforcement des compétences individuelles et collectives des équipes locales de développement à 3/5 ans. *Matri internal reports*.

competence at work in 2006–2007 in the case studied: informal interactions, cooperation, and management style. We will not go into further detail about the interviews here; their purpose was simply to enable us to identify the current and emerging collective competencies and analyze them. Here, we are more interested in identifying the nature and components of the collective competencies in the semiconductor industry 3–5 years out.

Next, we began to identify the collective competencies of tomorrow for the semiconductor industry. Our goal was to establish a 3–5-year forecast – but one that is solidly anchored in a thorough analysis of current individual and collective competencies to ensure that the forecast produced is reliable and credible. The people interviewed were carefully selected based on a social network analysis (see methodology sidebar).

Our analysis of the interviews, which aimed to identify future competencies 3–5 years out, enabled us to list seven types of competencies with both collective and environmental dimensions which are presented below.

6.4.1 Think and Manage Globally

For the project we studied, the company's France facility played a leading role and tasks had been assigned to Italy, the Czech Republic, or India only very recently. It was becoming clear that for a given project, tasks would be dispatched to locations worldwide (both within the company and at partners' locations).

In order to manage this change successfully, the project teams would need to develop individual and collective competencies. Namely, the project teams would need to improve their capacity to think and to manage globally on the following aspects:

- Overcome cultural and language barriers.
- Develop the capacity to negotiate with the team members serving as "interfaces." These people will need training in intercultural negotiation skills. The greater the cultural distances, the closer the hierarchical relationships need to be.
- Implement a learning process in the local and remote teams, to codify, standardize, and modularize their relations. Decisions concerning "interfaces" and the codification of relations must be made in as hands-on a way as possible, especially for the people who will deal with the consequences (or reap the benefits) of a lack of codification.
- Roll out data management tools will have to be looked into as a way of facilitating communication between teams and between different locations. Project managers will have to drive rollout of these tools and find ways to obtain the buy-in of project members and to convince them that additional individual effort (perceived as a waste of time) is crucial to the success of the group.
- Keep (and allocate additional resources) at the company's head office information-intensive activities requiring high personal interaction and focused on innovation and design, for instance.

6.4.2 Serve the Customer

The project we studied showed clearly a change in the boundary between the customer's organization and that of the organization designing the circuit/platform. The customer's participation in the new product design phase to ensure that the new products met the customer's needs is indicative of future trends. Providing the customer with quality service, working closely with customers, and securing customer loyalty will play key roles in the future. The competencies that will need to be developed here are:

- Knowledge of the scope of the company's development services and the services offered to customers upline from, during, and after development.
- Knowledge of the value customers' place on the different components of the service offered (what is offered and when).
- The capacity to be proactive and to work with customers (understand customer needs and how well customers know their own needs) and to engage in an iterative, long-term process based on perseverance and empathy.
- The capacity to widen the scope of work assigned to individuals to ensure that all skills are covered; to develop system competencies; to give people time to assimilate and master new information; and to develop the capacity to capitalize upon existing knowledge.

6.4.3 Absorb Knowledge Outside the Project Team and Capitalize on Knowledge Within the Project Team

In a future that will be shaped by meta-national innovation and open innovation, the capacity to acquire, assimilate, transform, and use knowledge outside the project team will be crucial. Changing this will require developing the capacity to absorb knowledge outside the project team and to leverage knowledge within the team, namely:

- Informal and formal sources of knowledge must be known to the project team.
- The role of knowledge broker played by people within the team must be known to all members; these people must be encouraged and promoted.
- Explicit and tacit means of communication must be analyzed.
- The performance of persons playing key roles in the acquisition, assimilation, transformation, and use of knowledge from outside the teams must be stepped up.
- Each member of the project team must be aware of his or her contribution to these roles and have the resources and time to devote to them.

6.4.4 Leverage Ongoing Learning and Skills Development

In the project groups, the members mainly capitalize on ongoing learning and skills development simply by doing their jobs from one project to the next. It appears that the need for new skills is increasing rapidly due to the fast-paced changes affecting the company's development services lineup. Therefore, the capacity to remain up-to-date and constantly learn and develop new skills is a source of innovation, a key differentiator.

To deal with this change, project teams must develop their capacity to capitalize ongoing learning and skills development by:

- Encouraging innovative behaviors in the search for new solutions, in terms of energy consumption, size, and cost.
- Using reverse engineering to analyze competing solutions.
- Documenting and disseminating innovative practices.
- Participating in outside events such as conferences and professional working groups and engaging in continuing education.
- Developing professional communities.
- Assessing the impact of outsourcing/offshoring and analyzing the emergence of specific skills at certain locations in order to understand their development curve, and leverage best practices.

6.4.5 *Use and Improve Upon Technologies Developed at Other Company Facilities and by Partners*

The know-how of tomorrow's project teams at the parent company's headquarters will be linked to an increasing extent to optimizing the pooling of a growing number of technologies developed at the company's multiple locations or by partners in Asia, in particular. To manage this change successfully, project teams must increase their capacity to use and improve upon technologies developed at other locations and partner technologies by:

- Identifying key technologies for the future.
- Explaining to each member of the team, with the help of a resource person with expertise in technology, how they can use and help advance the technology in question.
- Encouraging each member of the project team concerned by the technology in question to schedule visits to partners, participate in specialized working groups, and attend conferences (ensuring, of course, that the necessary time and resources are provided).
- Encouraging partners to come and work at the parent company, focusing shared projects on innovation.

6.4.6 *Use Local Resources Outside the Company and Contribute to Improving Them*

Given the increasing complexity of development services and processes, anchoring these activities in the region could constitute a significant advantage if the company is able to build strong relationships with local engineering and business schools for training, with development teams from other local companies for sharing experiences, with nearby suppliers for increased agility, and with research labs and businesses in complementary fields for access to targeted knowledge.

To manage this change successfully, project teams will have to increase their capacity to use and advance local partners outside the company by creating and implementing:

- Educational programs and training developed jointly with engineering and business schools to prepare project teams for the skills they are expected to need in the future.
- Feedback sessions so that each member of the project team, or at least each member of the core team, can share experiences with peers from other companies in the region.
- A schedule of meetings with local suppliers to assess each other's practices, provide suppliers with guidance on future changes, and to improve suppliers' practices.

6.4.7 Plan Ahead for Changing Consumer Needs and Understand How "Ecosystems" Work

Tomorrow's competencies will also be highly market- and consumer-oriented. Companies will have to respond as quickly as possible to consumer needs – which will no longer be exclusively the needs determined by the manufacturer; for instance, in the coming years, the cell phone could serve as a contactless payment system.

To plan ahead for this change and develop the needed competencies, project teams will have to:

- Develop services marketing competencies.
- Develop marketing competencies in the fields of banking and consumer behavior.
- Generate synergies with banking and financial services professionals (banks and payment and credit card providers).

6.5 Interorganizational Factors as New "Ingredients" in Collective Competence and in the Emergence of Interorganizational Competence: Analysis and Discussion

The results of our research reveal that, for high-tech companies operating in fast-paced, highly competitive international environments, collective competence can be created on several levels. The first and second levels are those put forward by Retour and

Krohmer (2006): individual and organizational factors. A third level became clear in our research: factors related to the environment outside the company. It appears that collective competence takes shape, is developed, and becomes solidly anchored only through the addition of "ingredients" that come directly from the environment outside the company. We observed that, while competency management can be broken down into five types (individual, collective, organizational, strategic, and environmental), it is clear that reinforcing and optimizing collective competence mean managing additional factors that come from the environment surrounding the group. We will now discuss the environmental and interorganizational factors in the development of collective competence; a proposed model for collective competence for high-tech companies; and a proposed new "kind" of competence that we feel is emerging: interorganizational competence.

6.5.1 The Emergence of a Third Pillar for the Development of Collective Competence: Interorganizational Factors

The results of our research highlight, for the case we studied, seven areas of competence that will play a decisive role in the development of a collective competence that includes an extraorganizational dimension.

6.5.1.1 The Intercultural and International Context

A prerequisite for the emergence and reinforcement of collective competence in high-tech industries is for the project team to be part of an international work environment. Further, in order for the team to be part of an international work environment, management – and the human resources that comprise all individual competencies – must be aware of the need to think and act globally on a daily basis. "Generic" intercultural buzzwords and knowledge of a few key concepts are not enough for this to take place. Because relationships are often still marked by a lack of understanding even after language and cultural barriers are overcome, a common set of operating rules must be established and approved by those most concerned.

6.5.1.2 The New Boundaries of the Organization

Going beyond the boundaries of the organization means changing the nature of those boundaries. In other words, the group must let other individuals or groups in (customers, suppliers, partners, and institutions involved with education and research) and go beyond what appear to be its own "natural" boundaries (toward new activities and fields). Beyond just management, each member of the group must be aware of this need – and address it rapidly – in their day-to-day work. The case studied here highlights how including customers in the design and development process is fundamental in meeting customer specifications and, perhaps more importantly, in creating and enhancing synergies that can optimize the final results.

6.5.1.3 Optimizing Technologies and Extraorganizational Resources

Partnerships are a decisive factor in high-tech product development. These include partnerships with suppliers, customers, researchers, and other units of the company located around the world, and, yet, these development – and sometimes operating – partnerships are but one stage. Teams must also learn, use, and improve upon technologies developed by all of their potential partners. The idea is to create additional leverage, capitalize on advances made by others, and push one's capacities beyond their current limits. This requires a high level of commitment from each member of the group to take on new roles and missions.

6.5.1.4 Managing Knowledge and Capitalizing on Competencies

Managing competencies outside the group appears to be a key process in the development of collective competence. Therefore, it is necessary to identify, acquire, assimilate, transform, and use knowledge from outside the team. Each member of the team must be given a specific role in the process in order to maximize investments and ensure operational returns. Furthermore, individuals who are capable of playing key roles in managing this external knowledge must be not only clearly identified, they must be supported as well.

6.5.2 A Proposed Collective Competence Model for the High-Tech Industries

The results of our research, i.e., the emergence of a new component among the factors that condition the appearance and reinforcement of collective competence, led us to propose a model for analyzing the appearance and reinforcement of collective competence in high-tech companies.

The model, which we present below, consists of three levels:

- The first level deals with the three types of elements that condition the appearance and reinforcement of collective competence, namely: individual factors (the assets that are individual competencies, affective interaction, informal interaction, and cooperation); organizational factors (team makeup, formal interaction, management style, and HR management drivers); and interorganizational factors (an international and intercultural context, the boundaries of the organization, technologies and resources, and internal and external competencies).

- The second level of the model states that the combination of these three families of elements facilitates the emergence and development of collective competence. We saw previously that the more prevalent these elements are (in both qualitative and quantitative terms), the greater the chance that collective competence will be reinforced; we also saw that the "intensity" of these elements can vary depending on the organization and its environment.
- The third level of the model considers that collective competence, once it emerges, is the main driver of collective performance (Bataille 2001). Collective performance, when viewed in light of the main meaning of collective competence, refers to the capacity to achieve greater levels of performance than those that can be attained by simply adding individual competencies together.

This enhanced performance can be seen in terms of efficacy, efficiency, and "effisens" [literally, "effective meaning"] with regard to the members of the team and the objective to be attained in an organization where the personal motives of the individuals that make up the organization are satisfied Barrand (2006). Collective performance has two major effects. First, it has a major impact on intraorganizational performance. In other words, it bolsters the overall performance of the organization through the specific performance of groups within the organization. There is also another more indirect, but nevertheless significant, impact on intraorganizational performance. The case studied in our research confirms this. We observed that the "collective competence–collective performance" equation is evident in a number of the company's departments. The methods, know-how, and attitudes developed by groups are observed and sometimes actively identified by employees and managers so that they may emulate them. We also saw how the process of benchmarking one project team against another to identify the best "equations" and practices based on individual, organizational, and environmental factors influences the emergence or reinforcement of collective competence.

There is also a major impact on interorganizational performance. Interorganizational performance is crucial for many industries, and especially for the high-tech industries. The competitive cluster development policy implemented by the French government is evidence of how crucial the interorganizational aspect is to enhancing performance. We feel that this aspect is strongly related to the management of environmental competencies, an area that merits further development and study (Fig. 6.1).

6.5.3 On the Emergence of a New Type of Competence: Interorganizational Competence

This again raises the issue of the boundaries between the different competence-related concepts and the different types of competence (individual, collective, organizational, strategic, environmental, and territorial). This only confirms that competency management is highly variable, in perpetual motion, singular, and multifaceted

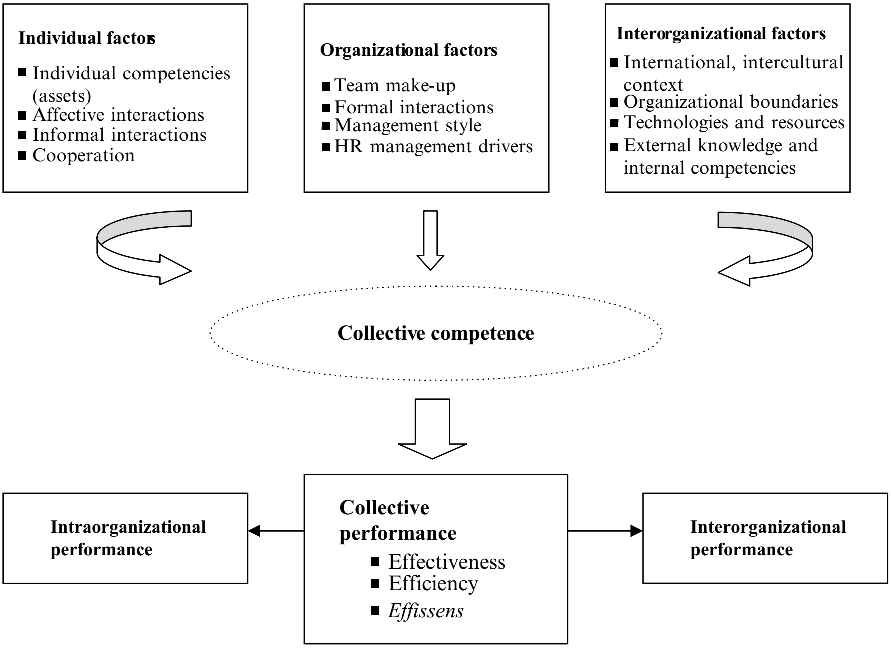

Fig. 6.1 A model for the emergence and reinforcement of collective competence in the high-tech industries

(Dietrich 2003), as well as context-dependent (Sanséau 2007). Therefore, competence is difficult to observe, it is multidimensional, and its definition fluctuates.

In the case we researched, it is clear that supposedly "external" competencies must be brought into the organization if collective competence is to emerge and be reinforced. If this is true, we must no longer address only environmental competence as defined by Retour (2005), but another type of competence as well, one that we will call "interorganizational competence," a concept observed and highlighted by Paul et al. (2004) and Prévot (2007). This new kind of competence refers to the organization's capacity to identify, capture, use, and optimize resources in its environment, to manage relationships with others in its environment, and to capitalize on resources and processes it needs to survive and flourish. Therefore, we are dealing with the company's capacity to develop and maintain a specific type of competence: interorganizational competence. On the other hand, the concept of environmental competence refers more to the competencies in the company's environment (locally, regionally, or in clusters), but outside of the direct control of the company.

We suggest the following as components of interorganizational competence:

- The organization's capacity to go beyond its traditional or natural boundaries by being more flexible and creating opportunities to work with partners and other parties (customers, suppliers, and other members of civil society), to penetrate their boundaries, and to allow their own boundaries to be penetrated.

- The organization's capacity to use, optimize, and capitalize on tangible and intangible resources belonging to its partners and present in its environment.
- The organization's capacity to manage and optimize interorganizational resources.

The concept of interorganizational competence has been the subject of research in the past that has attempted to deepen our understanding of the mechanisms at work.

Doz (1994) and Meschi (1997) showed that the process by which an organization develops its competencies takes place at two levels. A balance must be reached between maintaining the status quo and broadening the field of competencies by deepening current competencies and developing new ones.

Durand and Guerra Vieira (1997) made a distinction between static competencies (improving existing competencies and creating synergies by enhancing coordination of existing competencies) and dynamic competencies (access to networks, the capacity to learn, and developing the capacity for continuous learning). This can be considered new competency acquisition management (Grant 1996) or a capacity to acquire new competencies related to the environment outside of the company (Quélin 1997).

Several researchers point out the complementarity of resources. Teece (1987) explored the idea of co-specialized assets; Amit and Schoemaker (1993) spoke of complementary assets; and Miller and Shamsie (1996) pointed out the difference between discrete and systemic resources. Black and Boal (1994) put forward the concepts of simple resources and system resources. Nanda (1996) discussed complementarity of resources in an interorganizational context, putting forward the concept of marginal assets (assets specific to relationships between the company and its environment).

The concept of cooperation also offers insight into the concept of interorganizational competency. Cooperation drives knowledge creation and transfer (Hamel 1991; Powell et al. 1996), enabling access to partners' competencies and the development of new, shared competencies. This raises the need to link competencies that the company possesses and competencies that its partners possess in order to spark the emergence of new, shared competencies (Quélin 1997). Furthermore, the organization must reveal dynamic capacities to develop and integrate new competencies (Teece et al. 1997; Grant 1996).

Finally, the issue of interorganizational competency management has to do with organizational learning (Inkpen and Beamish 1997; Kale et al. 2000; Hamel 1991; Paul et al. 2004; Huelsmann et al. 2006; Runsten and Werr 2007; Chatenier et al. 2008). According to Hamel (1996), the issue of interorganizational learning refers to three situations: transparency, receptiveness, and the intent to learn.

We feel that the concept of interorganizational competence has its place among the other competence-related concepts that have already been identified and researched. Interorganizational competence has been identified, has content, and has been linked to the concepts of individual, collective, organizational, strategic, and environmental competence. The next step is to validate the concept through additional field research and analyses.

6.6 Conclusion

Our research led us to the following conclusions.

First, the case we studied showed that creating and reinforcing collective competence in the high-tech industries depends partly on interorganizational aspects working alongside with and interacting with individual and organizational aspects. This empirical reality shows clearly that collective competence is an assembly that comes together in a new way every time it is produced, but that the individual and organizational aspects of collective competence are not sufficient to explain its content, variability, and development. The interorganizational component is crucial in the case we studied. Other cases, both in the high-tech industry and other industries, must be studied to ascertain the scope and nature of the interorganizational dimension.

Second, we feel even more strongly that competency management is a broad topic that contains many subtopics and whose boundaries are difficult to define. Based on this framework for analysis, we identified the emergence of a new concept, interorganizational competency, and defined its components.

We also feel it is important to point out the benefits and unique added value of interorganizational competency as a way to bring new insights to help researchers and practitioners better understand organizational phenomena. It can also shed more light on two emerging concepts: environmental competence and territorial competence. Lastly, it offers a framework for organizations to implement actions to better manage competences shared by several organizations. We feel that this could be a new contribution to the field of competency management, one that merits further study.

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Chapter 7
The Leader–Member Relationship at the Core of Innovation Development: Member Perceptions, Positions, and Expectations

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7.1 Introduction

Innovation management is a core concern for high-tech firms. Over and above the strategic, technological, or production-oriented dimensions, the factor emerging as increasingly pivotal to whether innovation projects will succeed or fail is the way an innovation process is designed and managed. Innovation management seeks to deploy a raft of toolsets and methods for generating systems and solutions able to deal with an array of issues that can arise before, during, and in the post-innovation period (Baucus et al. 2008; Bernstein and Singh 2006; Fernez-Walch and Romon 2006). The battery of tools deployed is expected to foster reassurance by providing the innovation agents with security on both the structural and organizational dimensions involved.

However, the relationship and exchange issue turns out to be just as pivotal, as highlighted through several decades of research literature shedding promising insights into factors ranging from relations between innovation agents to leader–member exchange and back to teamwork dimensions and corporate group dynamics. The human, relational dimension is touted as an equally determinant factor in successful innovation (Scott and Bruce 1994; Carmeli et al. 2006; de Jong and Den Hartog 2007; du Chatenier et al. 2008; Baucus et al. 2008; Bernstein and Singh 2008).

This chapter looks into the specific issue of managing leader–member exchange in the context of innovation development. Starting out on the basis of topic-centered literature content, we aimed to pinpoint the drivers and challenges involved in the leader–member relationship in innovation-oriented settings at a high-tech firm in the semiconductor industry.

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Our assertions are organized into three sections. Part one begins with a review of the innovation management literature before honing in on relational management as a factor of innovation success. Part two sets out the research problem, contours the context, and details the methodology employed. Part three presents our analysis of the results.

7.2 Innovation Management: From Tools to Relational Exchanges Management

7.2.1 Tools Tailored to Innovation Management

The literature on innovation management harbors a wealth of methods and tools. Fernez-Walch and Romon (2006) proposed a classification framework centered on the key issues in innovation management, based on two criteria: decisional platform of the firm (strategic, tactical, and operations based) and the management focus (product design, costs, lead times, and organization). Table 7.1 recaps the tools deployed.

This table highlights three clear-cut approaches to using these innovation management tools. The tools shortlisted actually borrow heavily from financial investment (budget setting, aggregated budget curves, value analysis, etc.), knowledge management (shared databases and workflow software), and project management (Gantt charts, project management software, taskflow charts, product process charts, etc.).

These various classes of toolbox-based approaches share the same conspicuous absence of the human dimension in the innovation management tools deployed. While forced to accept this regrettable shortfall, our understanding is that the absence comes part and parcel with the societal and managerial paradigm through which the tools were spawned, i.e., an industrial society strongly branded by rampantly technology-oriented growth, and shunned by the leading contemporary thinkers.

This statement of affairs prompted us to explore the issue and show that innovation management has evolved from a more or less exclusively methods-and-tools-based discipline into a more relationship-oriented discipline.

7.2.2 Relational Exchanges Management: A Critical Success Factor for Innovation

It is, paradoxically, curious to witness how the human dimension is still a feature, if not the very foundation of every single creative act. An analogy with artists appears to be the best vector for illustrating the human dimension of the creative process. Any creation will always reflect the artist's personality, their subconscious, making

Table 7.1 Innovation management tools – a framework classification (Taken from Fernez-Walch and Romon 2006)

Management focus Decisional level within the firm	Efficient and effective design of new products and processes	Cost management	Lead-time management	Innovation planning
Strategic innovation planning	Environmental SWOT analysis Testing technological excellence	Project budgets package drafted to fit a target R&D budget	KPI metrics: average time span for innovation processes	Price of the innovation
Multiproject management	Workflow software applications Shared database	Aggregated budget curves for portfolio projects	Portfolio pipeline	Innovation itinerary Project portfolio pipeline
Innovation project management	Value analysis TRIZ Tech-specs on software needs for collaborative development platforms	Budget curve for milestones achieved Project management software	Gantt chart Project management software	Taskflow chart Product process chart Gantt chart Multicriteria project risks analysis

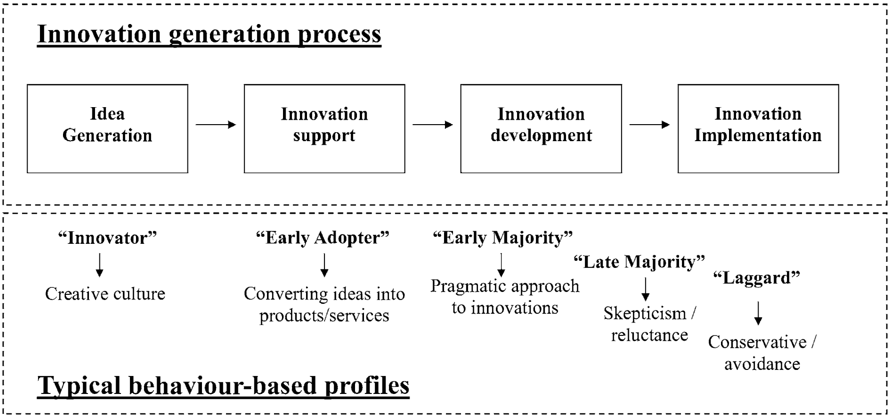

Fig. 7.1 Patterns of in-organization behavior throughout the innovation generation process, and examples of typical behavior-based profiles (Adapted from Bernstein and Singh 2008)

it permanently and inextricably tied to its creator. To draw the parallel with the innovation process, we draw on the four key stages in the Bernstein and Singh (2008) innovation generation process model and on the five innovation adopter categories in Rogers' diffusion of innovation model (Fig. 7.1). Bernstein and Singh (2008) chronicled how, as an innovation evolves from design through to market rollout, there is a concomitant progressive change in behaviors and attitudes within the organization engineering the innovation.

In order to clearly contour the behavioral issues tied into the innovation generation process, the authors identified and categorized the actions, activities, practices, and behavioral patterns of in-house stakeholders running through the five adopter categories labeled under the model. In their report, Bernstein and Singh (2008) showed that as ideas progress from the drawing board through to market rollout, attitudes also change, from enthusiasm to pragmatism then on to pessimism, and concluding in cynicism. The authors then took each phase in the innovation generation process and matched them to illustrative examples of typical features/behaviors that show through in the organization.

Our research, which is scripted into this model, focused primarily on the first three phases of the innovation generation process: idea generation, innovation support, and innovation development. This leads us to deal with not just the creativity input but also the governing climate and motivational environment surrounding the innovation.

Magakian (2006) surfaced three rationales underpinning creativity: functionalist mindset, interactionism, and poetic impulse. Each of these rationales acts as a creativity approach in project management. Under the functional mindset approach, creativity hinges on efficiently simulating the ties linking cause to effect. Under the interactionist approach, creativity is the fruit of interactions between the individual (their knowledge base, preferences, and personalities) and the group (its social setting, historical background, and organizational system). Finally, the poetic approach is impelled by creative imagination.

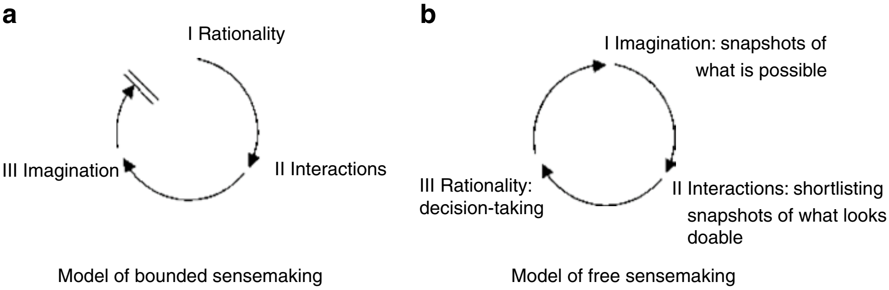

Fig. 7.2 Creative dynamics (Adapted from Magakian 2006)

Magakian (2006) asserted that a project-based approach that manages to create new groupwide practices dovetails all three of the above-stated approaches, as each is a driver of creativity. Creativity necessarily starts with envisioneering how a proposal-idea can fit into the environment. Rationality then kicks in with "a proposal-idea that acts as a poetic magnet, luring the actors into an intellectual quicksand from where they are forced to grab for a new set of actionable ideas, and thus to launch into interactions that themselves lead to new actions" (Magakian (2006):162). Magakian then demonstrated how creativity hinges on all three approaches, before going on to unveil the Essilor model that incubates the symbiosis of these approaches: Imagination, interactions, and rationalities (Fig. 7.2).

Magakian asserted that the model of pre-ordained thinking (a) straightjackets the human agent's imaginative dimension in a boxed-in reality, with the result that the individual switches off, cynically alienated within their organization. However, the model of unshackled sensemaking adopted by Essilor (b) exploits an alternative approach. The process starts by giving free reign to the imagination, after which the agents are allowed to interact to select pictures of what appears feasible, the final outcome being a set of rationally forged decisions that, once implemented, revitalize and feedforward the process.

The author is quick to underline that the rationality process starts out with or at least is given impetus by tapping the imaginational dimension, thus leaving the process of creation unbridled Then and only then can the interactions – and consequently decision making – begin.

This approach to creative dynamics mirrors the agile enterprise model developed by Barrand (2006), which also seeks to place freewheeling imagination at the heart of innovation. Barrand asserted that innovation is and has to be the result of creative foresight (imagination) and pro-operation (interactions). It is the cross-fertilization between divergent minds envisioning potential futures and inter-individual exchanges that spawns greater creativity and sharper innovation.

Bernstein and Singh (2006) also discussed the importance of communication, spotlighting the exchanges between creative problem solvers and their managers during the innovation support and innovation development phases of the innovation generation process. They claimed that this relationship looks to support and safeguard the organizational resources needed to develop the new idea. Going forward, they add that during the development phase, the ties and exchanges between team members and the other cross-organization functions gain in importance (ties with marketing to develop the features required by customers).

This prompts the view that interpersonal management has now become a critical success factor in organizations. The next section expands on how leader–member exchanges shape innovation performance.

7.2.3 The Leader–Member Relationship

The manager patently takes a key role in innovation development, making it unreasonable to confine this role to a straightforward methods-related issue. That said, since any relationship has to have at least two agents, each party has an equally important role to play. The roles focused on here are 'leader' (manager) and (team) "member."

The last few years have marked the emergence of a hot new management science theme: Individual innovative behavior, defined by Carmeli et al. (2006) as a complex behavior set that revolves around a three-phase process. In the first phase, the individual recognizes a problem and finds new solutions and ideas, which themselves may be novel or adopted. In phase two of the individual innovative behavior process, the individual seeks out ways to promote their solutions and ideas, building legitimacy and canvassing support both inside and outside the organization. Finally, in phase three, an individual demonstrating individual innovative behavior materializes their idea/solution by building a prototype or a model that can then be trialed, delivered, and implemented, by either a taskforce or straight to organization-wide rollout.

The field literature addresses this individual innovative behavior concept from two stances: the role of the leader–manager in this behavior pattern and what the member–follower does with this behavior.

- Role of the leader in individual innovative behavior.

Scott and Bruce (1994) viewed individual innovative behavior as the outcome of four interdependent systems: individual, leader, workgroup, and climate for innovation. Their results show that climate for innovation, leadership, and proactive innovation support all correlated significantly with individual innovative behavior. Their study also delivered proof that individual innovative behavior is related to the quality of leader–follower exchange, and that subordinates will extrapolate their perception of this relationship to the organization as a whole. Janssen (2005) added further weight to this argument, asserting that employees' motivational drive to get involved in the innovation process can be dependent on their perceived degree of influence in the workplace. Employees that believe they have leverage are readier to make efforts to generate, promote, and carry through innovative ideas. From an organizational perspective, employees are highly dependent on their supervisors for informational input (data, opinion leadership, and political intelligence), resources (equipment, space, and time), and socio-political support (backing, legitimacy, and coaching) to develop, defend, and deploy their new ideas. The supervisor's role clearly surfaces as a facilitating factor to individual innovative behavior. When the employees' perception is that their supervisors form an appreciative audience supportively handling their innovations, the stimulation is there for them to use their influence as leverage to win agents around to supporting the development and realization of the ideas that they have championed.

Janssen (2005) clearly showed that supervisors occupy a pivotal position in fostering individual innovative behavior, as they are the people who employees see as key actors, holding the power to grant or refuse them the heavier backing needed to take things further, guarantee protection, and apply their ideas in an environment potentially hostile to innovational change.

de Jong and Den Hartog (2007) fine-tuned this approach, listing 13 leader behavior profiles tabled as influencing individual innovative behavior. Of these 13 behavior-based profiles – most of which count as leadership styles – the authors shortlisted two as standout factors: the creation of a pro-innovation climate and giving employees the opportunity to have independent work contacts. They also signaled how the way leaders structure the workplace environment has an indirect effect on individual innovation.

The overarching results of this research were confirmed by Amabile and Khaire (2008) in a paper published by the *Harvard Business Review*. The authors presented highlights of discussions between academics and in-field researchers studying key challenges of the creativity process and where the manager's role becomes operative. The exchanges took place at the "Creativity, Entrepreneurship, and Organizations of the Future" colloquium hosted by *Harvard Business School* and convened with the aim of connecting theory to practice. Amabile and Khaire (2008) authored a manager's guidebook to enhancing creativity and increasing innovational input. They assert that managers seeking to enhance creativity should focus primarily on facilitating creative collaboration (by both promoting behaviors that lead from the front and employing 'coordination totems' to help teams co-conceptualize) and proactively incorporating diversity (teaming together people from different branches or with different career paths, opening the organization up to creative outside contributors). Managers seeking to increase innovation should focus their efforts on shaping creativity phases and catering for phase-specific needs (scaling and injecting resources enabling discoveries, etc.), on accepting failures as inevitable and profiting from lessons learned (foster a psychological security buffer freeing room to allow trial-and-error learning, and recognize errors and embrace them as useful), and then motivating teams by setting intellectual challenges (granting greater autonomy, trusting the agents involved, etc.).

Academic research, by turning the spotlight on creative collaboration, diversity and lesson learning as a source of progress, plus being in touch with the team, workplace climate, exchanges with outside, perception of people's influence spheres, forms of recognition, and so on, has sealed the importance of interpersonal management as a facilitator of individual innovative behavior – and by the same token leads us toward the question of ethics.

Janssen (2004) demonstrated that when the organization applies fair and equitable procedures, its innovators will tolerate a lack of distributive equity in their exchange relationship with the organization, meaning that their innovative efforts will generate only low levels of stress. However, experimenting with inequitable procedures will tip the balance of innovators' control and confidence in the exchange process into a downward curve, fueling uncertainty and doubt over whether there is an equitable two-way respect for their demanding innovation efforts.

However, and as flagged by Bouchard and Bos (2006), organizational creativity research, over and above the role of the leader–manager, spotlights the role of the individual as pivotal to the creative process, with the knock-on effect that firms seeking to increase their creativity are forced to implement people-oriented action policy. Our line of thought thus turns logically to the member individual.

- How the member–follower uses this innovative behavior.

Kleysen and Street (2001) pointed out five factors matched with respective behavior-based profiles as the sharpest way to categorize individual innovation-related behaviors:

- Opportunity exploration: ability to travel innovation opportunity pathways to learn and discover more on the paths involved. Tied-in behaviors are opportunity recognition and searching, receptiveness to opportunity sources, and opportunity-related intelligence gathering.
- Generativity: generating changes that are beneficial to the development of an organization, its employees, products, processes, and services. Tied-in behaviors deal with the generation of ideas, solutions, conceptions, categorizing the opportunities, and ways to pair and combine ideas and information content.
- Formative investigation: fleshing out ideas, solutions, and opinions, and trialing them out. The referent behaviors are turned toward formulating, experimenting, and assessing ideas and solutions.
- Championing: champions are individuals who incubate creative ideas and breathe life into them. Their behavior modes are patterned by resource mobilization, persuasion through influence, persuasion through negotiation, risk taking, and rising to challenge.
- Application: working to push the innovations as an integral part of everyday business practice. The tied-in implementation, readjustment, and routinization behaviors prove sufficient.

This broad panel of individual innovation-related behavior profiles proposed by Kleysen and Street (2001) was revisited by Baucus et al. (2008) who defined four behavior categories emerging through innovation theory and seen to foster creativity: breaking with the rules and standard operating procedures (preparing the ground for fresh new mindsets); challenging authority and breaking with traditions (skipping over mutual obligations and conventional boundaries); creating conflict, competition, and stress (looking for the best idea possible); and risk taking (to test out bold new ideas and approaches). Baucus et al. (2008) also demonstrated that these four behavior profiles can quickly overstep the ethical boundaries and trigger major organizational issues. Thus, ethics, as explored in the previous section, quickly rises to the fore, especially in English-language publications.

Management literature features an extensive variety of startpoints on this issue. Carmeli et al. (2006) investigated the relationship between self-leadership capabilities (where self-leadership is a process through which individuals gain motivation and lead themselves toward self-targeted behaviors and goals) and individual innovation behavior. The authors outline how self-leaders demonstrate high-skill individual innovation behavior that can be actively promoted through efforts targeting increased behavioral focus, and through intrinsic rewards, and how income is positively related to individual innovative behaviors at work. Scott and Bruce (1994) studied the negative relationship between individual innovative behaviors and systematized problem solving. Their research revealed that individuals do not actually need to possess highly intuitive problem-solving capacities in order to be innovative, but the results also suggest that systematizing the problem-solving process appears to act as a barrier to high-level innovative behaviors. du Chatenier et al. (2008) later investigated the professional competencies required for inter-organizational learning in open innovation teams. Their final shortlist included autonomy, entrepreneurship, coordination, knowledge sharing, and negotiation. Yet again, we run into the relational aspect.

Finally, we would like to add a word on the impact of affect on group dynamics, particularly in workgroups (such as an innovation project taskforce). Our position is that there are critical links to be drawn between interpersonal exchange management and the role of affect in group activity. Rhee (2007) asserts that research teams have recently begun to explore emotions as a collective group attribute, stating that this research distils into two types of study: studies on the mood of the group (handling shared emotions as an unshifting group attribute) and studies on emotional contagion and emotional convergence (handling shared emotions as a temporary, shifting group attribute that emerges through member–member interactions and social sharing of emotions). Our line of analysis is therefore seated far more strongly in this second study stream, which tends to reinforce the vision of innovation channeled through the agile enterprise model Barrand (2006), where innovation is perceived as the combined output of foresight (based on proactive and intuitional behaviors) and pro-operation (based on systemic empathy behaviors and receptive synchronization).

7.3 Research Frame, Objective: Decisive Factors and Challenges Facing Leader–Member Exchange in Innovation Development

7.3.1 Research Problem, Context

The research problem tackled here was to build greater insight into the patterns and practical challenges of leader–member exchange in innovation development, as seen from member–employee viewpoints. A literature review surfaced two specific areas of focus: the role of the leader in the individual innovative behavior (of the member) and what the member does with this innovative behavior.

This dynamic issue was surfaced through input from the literature and an organizational situation analysis in an innovation-oriented setting. A research project designed to spotlight the competences orienting 3- to 5-year differentiation in the European semiconductors industry gave us a framework in which to run a two-phase inquiry. Phase one (which is not outlined here): identify individual and collective differentiation points at a 3- to 5-year horizon. Phase two: engineer and implement a full, end-to-end process developing these competencies. The research focus studied here is part of phase two.

We had discovered that despite the importance of developing manager–leader and employee–member competencies to improve leader–member exchange, which is key to innovation management, it was essential to first gain deeper insight and understanding into how members actually perceive this relationship.

Several questions needed addressing:

- What are the decisive factors governing leader–member exchanges in an innovation-oriented setting?
- What are the managerial-strategy facilitators mobilized by leaders in an innovation-oriented setting?
- Which of the managerial-strategy facilitators mobilized by leaders are most decisive for innovation?
- What perceptions do member employees hold of leaders and leadership in an innovation-oriented setting?

Our stance here is clearly a perception-oriented approach. The core focus of our research is this: what perception do member employees hold of leader–member exchange in innovation development?

7.3.2 Methodology Guide Marks

The research field is a European microelectronics company (with offices worldwide) ranked among the top five industry leaders. Its core business is the development and manufacture of new products in the semiconductor industry (mixed signal and analog).

We led a qualitative study employing semi-directive group surveys. Two researchers led a two-hour, semi-directive group survey polling a sample population of nine member-employee engineers from the company. The group was selected randomly from a target population of member-employee engineers employed at a site based in France.

The survey was conducted via questionnaire in "Régnier abacus" format. The principle underlying the 'Régnier abacus' system is to build short-statement how-far-do-you-agree questions and to match the responses to a rating scale materialized through a color system. As respondents edge closer to 'totally agreeing' on a statement, the associated color gets darker. This method makes it possible to factor in and consolidate individual opinions. François Régnier created the method in 1973 to compensate for nonexpression from individuals in group-based sessions (apprehension addressing superiors, timidity, problems with spontaneous expression, etc.), which often results in high-value-added ideas being stifled and lost.

Fully agree	Tend to agree	Neutral	Tend to disagree	Disagree	I don't know	I would rather not reply
Dark green	Light green	Yellow	Orange	Red	White	Black

We found that the best solution for tackling relations and emotions would be a method enabling perceptional expression and opening up freewheeling discussion. Expressing opinion through color is an effectively geared method. Following literature review and analysis, we defined 58 affirmative statements split across 11 focus areas. Targeting the research problem tackled in this paper, 35 of the statements used were directly tied to member–employee perception of leaders and leadership in an innovation-oriented setting. Annex 1 reports these 35 statements in boldtype. This evidence-gathering process was carried out in December 2008.

7.4 An Analysis of the Results Output

This section presents our analysis of the results output. The data used are taken both from the factually recorded color-coded responses and from comments raised while going back over the image with the group of respondents.

7.4.1 Managing Variable Time Courses

While the time factor (statements 1–4) is widely recognized as ultimately compulsory, it appears that project scheduling, i.e., the breakdown of the innovation project into a sequence of phases, has to be both flexible and rebaselinable. The respondents quizzed were unanimous in confirming that the perception of time really is different for different projects and different people. This means that meeting deadlines is only achievable if, as underlined by de Jong and Den Hartog (2007), the manager is able to breathe diversity into the team – in this scenario, diversity in perceptions of time course. It is through these differing perceptions that a key behavior surfaces: to move forward and take initiative, and especially to innovate, each member of a company has to be ready and willing to recognize difference in the people facing them. The business ecosystem in which firms now work (internal interdependency plus interdependency with customers, suppliers, regulatory measures, etc.) has meant that, first off, it is no longer possible to work in blissful isolation, ignoring other agents and their perceptions and aims; from that point on, it has become equally impossible to work (decide or act) without factoring in the consequences of our acts at several levels (some direct, but also indirect tier-2, -3, or -4 levels). This resets the aim as identifying whether the firm is being drawn into a vicious circle or a virtuous circle of consequences. This "consequence-informed" form of leadership is the keystone of agility (Barrand 2009). It is also, as highlighted in this first time-course example, the key stance for creating a cooperative, creative climate.

7.4.2 Leadership and Mobilizing the Corporate Group

When quizzed on the corporate group dimension (statements 5–9), the respondents were virtually 100% unanimous in their feedback. The corporate group's talent capital stems principally from the diversity of the people profiles, provided this diversity is understood, accepted, and handled appropriately. This perception further reinforces the previous discussions on the time factor, leaving room to add that choice of team members is globally considered an essential factor – even if it is not always a viable option. It should be underlined that this choice implies not just competencies but also personalities. However, performance does not revolve around team-member selection alone; it also hinges on the adoption of shared operational stances and embodying the group through an authority figure whose role is both guide and protector. Extending on the ideas championed by Scott and Bruce (1994), our sample of "member" engineers confirmed that the leader needs to focus on the quality of their exchanges with subordinates. The leader is responsible for sense-making, creating the climate, instilling shared stances, and giving the members drive or even coaching them while leaving varying degrees of freedom for creativity to come through. The discussions surfaced a consensus on the fact that firms have to exploit the principle of synergy. However, this synergy can only resonate if it is accompanied by specific work sharing and open transparency-based behaviors, and only if the team really does manage to share the same joint goal and leave their own individual motivations aside. With this kind of work optimization, there is an all-round agreement on the fact that corporate-team performance has to outweigh individual performances.

7.4.3 Management of the Member-Individual: Opt-in, Guidance, and Self-Leadership

The responses on how to manage the member-individual (statements 10–14) repeated the same pattern: a consensus did emerge to consent that managing does mean knowing how to listen, guide, and reward each individual team member. There was clearer consensus to conclude that managers have to adapt and adjust to each individual, and recognize, or possibly even actively affirm their different personalities, adding weight to the trends previously observed. That said, the consensus broke down (five light green, two orange, one light red, and one deep red) over the item concerning manager control over individuals in innovation-oriented settings. The respondents were ready to believe in self-leadership or in control exerted by readjusting interpersonal behaviors, but less so in control by the superior. Siding with Bernstein and Singh (2008), the manager's role is centered more on offering guidance and support, securing organizational resources and endorsing the work setting. The more control the manager "takes," the more they risk suffocating the innovation process.

Statements 18 and 19 go on to confirm this analysis, highlighting that if a team manager's aim is to bring out innovation, they have to know how to bring each member into decision making (statement 18), and that doubling or tripling the number of line management levels (statement 15) is perceived as signaling counter-innovative overstructuration. An important lesson highlighted in the collated responses is that there are different degrees of acceptance of a project management hierarchy – indeed, this was one of the items on which there was greatest dissensus – fueling debate on team autonomy or control through relational interplay. Finally, opinion converged all-round to recognize that the relational climate is more critical to the innovation process than structure and organizational variables. The responses confirmed the position taken by Magakian (2006) on the innovational *inefficiency* of bounded sensemaking and, in contrast, the innovational *efficiency* of free sensemaking.

7.4.4 Affect-Based Management of Recognition and Reward

This relational sensitivity becomes concretized as we address the statements on reward (25–29). While it is unanimously understood that each individual is receptive to different forms of reward, it is equally widely accepted that recognition cannot be expressed in the same way for each team member, and that recognition is a more moral, relational construct, indexed more to sensitivities and emotions than to money. Our research also revealed that the follower-member is more receptive to emotional signals than material signals. Furthermore, this sensitivity, which we see expressed here through leader–member exchange, needs to be gauged on the same level as member–member exchange.

7.4.5 Work Organization: Beyond Rules and Control

The respondents generally refused any oppressively policed organizational setup. They do not perceive innovation as something that can easily filter through uniform methods or scientific work organization (statements 31 and 32). Although these two points drew little consensus and the responses came with nuances, the majority expressed themselves in oranges, reds, and light reds. This contrasts with the majority of greens in the matrix for the statement that the "right organization" for innovation hinges on setting operating rules (statement 30). This item did draw some light reds and oranges, more to demonstrate issues with the word "rules" than the idea that the right organization involves a cohesive team-wide set of behaviors and sincere emotional ties between the people or departments mobilized. The respondents gave strong cues that they harbored the genuine conviction that innovation is more the fruit of shared drive and relational–emotional leadership than a leadership based on rules and controls. So much so, in fact, that their conviction stretches to seeing absolutely no danger in giving greater responsibility to unqualified staff (statement 33), which goes to show just how blindly they trust in these exchanges.

7.4.6 Reaffirmation on the Pivotal Role of Communication

The perception of our respondents is that creating frictionless exchanges through transparent information management policy is key to success. They were unanimous in defending communication as essential (item 35 totally red!) because not everyone in a company is kept informed on everything. There was clear, although less categorical, unanimity to defend vision (item 36 on strategic information) as pivotal to team performance. They perceive information as the vector driving intra-and/or inter-team dialog – a vector that should be managed like a process flow, i.e., a continuous loop. All information should be transparent, readable, instantly accessible, and useful. It should not be a source of power (statement 37) but a source of performance. Unfortunately, in the real world, too many people still cling to information as power, thus choking the corporate team's innovation performance. This logically leads into the idea that information management should be 100% centralized – an idea materialized in the relative dissensus on statement 39 that netted all the color responses possible except black. The debate session on this point revealed that information is indeed a key to unlocking communication and behavioral group dynamics. Perceptions diverge, and behavioral responses vary; yet, the hurdles to efficient and effective team performance start here.

7.4.7 Co-construction as an Environment Management Blueprint

The respondents claim that their environment leaves them two options: either live under rule, and follow the same well-trodden path, or reinvent the how and why of what they do. However, their own opinion is that the organizational agility so badly needed, especially for fostering innovation, is more likely to come from arrangements co-constructed with the actors involved in sensemaking (statement 45) than from hierarchically driven, top-down rulesets. They agree that innovation means not just generating new products or process technologies, but also top-to-bottom transformation of the organization itself (statement 49). Innovation therefore consists in focusing exclusively – and with sincerity – on the customer's need, and in understanding how to create conditions stimulating creativity rather than how to implement any given design-cycle method (statement 52). Lastly, innovation does not have to mean either destruction (statement 55) or going faster and faster (statement 54). Innovation is not, therefore, a relentless pursuit; it is just a resource to be deployed when dictated by customer needs. That said, it is widely recognized that innovation is synonymous with risk taking, and is spurred by audaciousness (statements 57 and 58).

7.5 Conclusion

The research results shed considerable light on the issues raised. To recap, our research direction was designed to shed deeper insight into member perceptions of the leader–member relationship in an innovation-oriented setting. We took the member's perception of this relationship as our stance in order to go a step further than the management literature sources, which generally tend to take the position of the manager in comprehensive, analytical, or prescriptive stances.

Team-member opinion suggests that in innovation-oriented contexts, management leadership should demonstrate:

- Management focus on the team group: the team outlook should be taken in preference to individualism and personality profiles, and requires real concerted management: team-member selection, shared operational stances, and re-adapted leadership.
- Management focus on member diversity: conscious awareness among leaders of the existence – and subsequently the potential – of team-member diversity is capital. Diversity should therefore be integrated into leadership behavior and managed as a resource in order to impart meaning and aim.
- Management focus on self-leadership: team control and assessment should be handled via group self-policing, with the leader's role re-centered on recognition and guidance.
- Management focus on information flows and federating decision making: managing innovation starts with informing and enrolling the team members in decision-making processes, skipping over the hierarchical decision structure. Management of the relational climate is a key innovation driver, whereas leader reliance on hierarchy-grounded rationales acts as a barrier.
- Management focus on interpersonal skills and recognition: innovation hinges first and foremost on the drive and motivation of team members and on the leader's ability to impel. Furthermore, the pivotal factor, far more than financial reward, appears to be the manager's capacity to show emotional recognition signals.
- Management focus on situational organization: organizational development and adaptation are critical to innovation, and the manager-leader plays a key role in 'creating' of conditions conducive to risk taking.

These six core criteria give a clear picture of the requisite conditions for deploying and developing managerial action in an innovation-oriented setting. They also underline the leader's role at the hub of the innovation process – a position reflected in the perception of the team members, who see their leader as a key figure holding an essential role: to lay foundations, capture and handle affect and emotion, be in touch with the team, and give firm guidance. This research, led from the team member's perspective, reaffirms that the team leader is still the key actor in innovation ecosystems.

Annex 1 "Regnier abacus" – the questionnaire

The items analyzed in this research are reported in boldtype

A	*Managing time/scheduling/deadlines*
1	A project group should consider the time factor as a stone-cold imperative
2	**A task schedule is always flexible and rebaselinable**
3	**The individual members making up our company share an identical perception of time**
4	**The perception of time stays identical, whatever the project**
B	*Managing the corporate group*
5	**The group's talent capital stems from complementarity between the individual member profiles**
6	**Choice of team members is important leverage for program success**
7	**A project team needs the authority of a manager in order to tick**
8	**The strength of the corporate group lies in the principle of synergy (2 + 2 = 5)**
9	**In a team, individual ambitions are outweighed by the net performance of the group**
C	*Management of the member-individual*
10	**Managing an individual means understanding how to listen to them**
11	**Managing an individual means knowing how to guide them forward and coach them through**
12	**Managing an individual means exerting control (on performance and operations)**
13	**Managing an individual means knowing how to give recognition and reward**
14	**Management of the individual will be led differently in different situations (baseline output, incremental innovation, breakthrough innovation, etc.)**
D	*Handling line management*
15	A firm needs a high number of line management levels
16	**Line management is core to any project**
17	In a project, the project leader has totally free latitude within a budget package and a timeframe
18	**A project leader needs to know how to get the team involved in decision making**
19	**Line management's role will be different in different situations (baseline output, incremental innovation, breakthrough innovation, etc.)**
E	*Handling performance*
20	Performance also means achievement of an ultimate aim
21	Performance also means the right mix of resources deployed

(continued)

(continued)

22	Performance also means achieving results without social cost
23	A successful project is an innovation that gets to see daylight
24	Failure can sometimes be seen as a source of progress
F	*Handling reward*
25	Rewarding a team member means giving them financial reward
26	**Rewarding a team member means giving them recognition (attention, greater independence, promotion, time, etc.)**
27	**Reward needs to be the same for all team members**
28	If a firm wants to get performance, it continually needs to have both carrots and sticks
29	**Not all individuals are receptive to the same forms of recognition**
G	*Handling workflow organization/procedures*
30	Work organization starts by setting operating rules
31	Group work requires harmonized method sets
32	**Work should be organized via a scientific approach**
33	Giving greater responsibility to unqualified staff is a risky, dangerous business
34	**It takes innovative organizations to conclude an innovative program**
H	*Handling informational exchange*
35	Communication is not really necessary, given that all the information is there
36	**Circulating strategic information will end up sapping the morale of the troops**
37	**Information is a source of power**
38	**Information should be handled like a flow**
39	**High-performing companies centralize the management of their information content**
I	*Customer relations management*
40	Customers need to be satisfied on several criteria at the same time
41	You have to be firm with customers
42	All of my contacts (internal and external) are process customers
43	I am the first customer to all of my contacts
J	*Environmental management*
44	The only factors that can hold us back are technical
45	**The top-down rules laid down by line management have now been ousted and replaced by agreements co-constructed bottom up by the agents involved**
46	There are always options for bypassing environmental (=ecological) regulations
K	*Innovation management*
47	Innovating means taking a technological leap forward
48	Innovation starts with fully understanding the full set of customer expectations
49	**Innovation also means organizational transformation (line management structure, management, culture, behaviors, etc.)**
50	Innovation means ushering in just the right dose of change
51	Only creative people can innovate
52	**Innovation hinges on the method (framed design cycle)**
53	The original idea is always a one-person creation
54	**Innovation has to keep going faster and faster**
55	**Innovation means destruction**
56	**Innovation means risk**
57	**Innovation means taking a gamble**
58	**Innovation means creating value**

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Chapter 8
A Stepwise, Actor-Based Approach to the Establishment of Science–Industry Co-operations

Joachim Hemer and Henning Kroll

8.1 Introduction

Science–industry co-operations (SIC) have, from various perspectives, been a major subject of interest for innovation studies during the past decades. In the course of extensive academic discussions it has become commonly accepted that the exchange of knowledge and the transfer of technology between the scientific and the industrial sector is based on an interactive process of personal exchange between many actors from different fields of science and industry (e.g., Bonaccorsi and Piccaluga 1994; Leydesdorff and Etzkowitz 1996; Etzkowitz and Leydesdorff 1997; Leydesdorff 2000; Thune 2006; Backes-Gellner et al. 2005).

One of the issues not yet comprehensively addressed by existing theoretical and empirical work is the process of the emergence of a co-operation before the first agreement is reached. To a large extent, questions have remained unanswered such as: In what way do potential R&D collaboration partners initiate the process of co-operation? Based on which consideration such co-operations emerge? What is the nature of relations between the potential partners during the preparatory stage? If at all, most available literature deals with this subject either in the context of a rational choice-based approach (Carayol 2003) or from a birds-eye systemic perspective (Etzkowitz and Leydesdorff 1997).

This chapter, in contrast, will argue that, with regard to a process which is based on deliberate action and quasi-entrepreneurial decisions, an approach with a comprehensive focus on the key driving actors can better contribute to a understanding of how co-operations develop than a system-based approach or a rational choice approach that disregards personal characteristics. It will argue that neither purely actor-based nor purely institution-based approaches alone makes for a good explanation, but that, conceptually, both are required. More precisely, it will attempt to strike

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a balance by taking the actors' decisions as the main foundation of the analysis while considering institutional and organisational factors as mediating framework conditions. The most important factors to be studied, therefore, are first the actors' rationales, aims, strategies, and motives that drive the process of establishment of an SIC and, second, the different institutional determinants that impact on and shape their actions.

To do so, this chapter will briefly review existing conceptual literature and then review case study evidence that Fraunhofer ISI[1] has collected during its practical work in this subject field in the course of the past decade in the light of the conceptual notions following from it. On this basis, a conceptual approach to analyse the early stages of cooperative agreements will be developed.

For the purpose of this chapter we will focus on *bilateral* R&D co-operation[2] or partnerships based on *direct R&D interaction* of employees from both sides, excluding other forms of technology or knowledge transfer (patenting and licensing mediated through TTOs, joint creation of start-up companies, long-term recruitment of personnel, unidirectional transfer via publishing or giving lectures and presentations, etc.). Secondly, we assume that the industrial actors, large or small, are independent, i.e., can take independent decisions on whether or not they engage in R&D collaborations. Finally, as this chapter aims to establish a first general approach, strong ceteris paribus assumptions are imposed with regard to differences in technologies, science fields, or sectors.

8.2 Emphasising the Actor-Based Component of Science–Industry Co-operation

Very often, university–industry relations are examined in structural terms by classifying them according to their legal or organisational set-up (cf., for instance, Meyer-Krahmer and Schmoch 1998; HMSO 2003; Carayol 2003; van Horne et al. 2008). All developed countries, but particularly Europe, dispose of a broad variety of forms of research collaboration between companies and R&D establishments (see Koschatzky et al. 2008:36–41; Hemer et al. 2006:71–87), among them:

- Individual research contracts.
- Framework contracts with universities.
- Testing, measurement, and consulting services.
- Research contracts with legally independent institutes attached to universities (American UIRCs or German "An-Institute").
- Temporary collaborative partnerships (British "Teaching Company Scheme", "Knowledge Partnership Programme", "Faraday Partnerships", etc.).
- Exploitation contracts arranged by technology transfer/patent licensing offices.
- Experimental forms of public–private partnerships (PPPs) or strategic alliances between universities and industry.

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[2] Here we use collaboration as a synonym to co-operation.

Years ago, direct contractual co-operation or, at best, framework contracts were the most common form of cooperative set-up between research organisations and industrial enterprises. A view into the literature suggests that this has fundamentally changed. Science–industry relations cannot or at least can no longer be conceptualised in terms of an interchange between two clearly delimited fields (Gibbons et al. 1994; Etzkowitz and Leydesdorff 1997). In very few cases, science–industry relations are established for the sole reason to outsource pre-specified work. Instead, the establishment of long-term partnerships for know-how development and the development of networks has become more important. It can be observed that science–industry co-operation has become an activity that by itself may create new organisations (spin-offs, legally independent institutes at universities, public–private partnerships PPP, etc.) (Koschatzky et al. 2008). Later, these organisations, which have emerged from past collaboration by themselves, play a role in the establishment of new project consortia.

Additionally, a number of third–party organisations are directly involved in the process of science–industry relations. One subgroup of those are public intermediary institutions such as technology or innovation centres, incubators, technology transfer or patent and licensing offices, which try to guide the process directly and are often directly involved in cooperative efforts (cf. Schmoch et al. 2000:318–352). A similar and increasingly important player are cluster platforms – intermediaries with a broad and active mandate (Bührer et al. 2008).

A very close and confidence-based form of co-operation are modern forms of public–private partnerships, in which an industrial partner sources out much of its activities to an institute which may be established exactly for this very purpose (e.g., a specific development project of the company) and which it owns jointly with a public university (e.g., German Telekom's T-Labs in Berlin). Work in those institutes actively blurs the boundary between the industrial and the public sector's scientific working cultures even if a significant degree of understanding between the two partners has to exist before such a venture becomes viable.

It must be emphasised, however, that we do not intend to add another typology of forms of SIC to the number of existing ones (see, for instance, Carayol 2003; Backes-Gellner et al. 2005; van Horne et al. 2008). For the aim of this chapter, we maintain that all static typologies can at best provide a first step if one is to achieve a better understanding of the processes that actually drive the initiation of SICs. By definition, they take an ex-post perspective, whereas, typically, SIC go through a number of stages of development so that a mere look at the outcome may conceal the origin and the succeeding steps.

In summary, the establishment of science–industry co-operation needs to be understood as a process driven by interpersonal knowledge exchange and negotiation, while the impact of the institutional and organisational context needs to be acknowledged. Consequently, the key issue to be dealt with in this chapter are the driving factors that determine the readiness of individual actors on both sides[3] to enter into concrete negotiations to cooperate and what are the framework conditions that modify the outcome. The precise form of the co-operation, in contrast, is of less importance.

[3] For the sake of simplification we follow, here, the model of bilateral collaboration.

8.3 Methodological Approach

8.3.1 Towards a Stepwise Model

As laid out in the introduction, it is the aim of this chapter to collect information from multiple sources with regard to both personal and institutional factors that determine the process of entering into R&D collaboration in order to subsume them into categories and to assess their relevance.

Literature tells us that the core of crystallisation for a co-operation agreement is often a first encounter of key actors, at conferences or in expert circles. Typically, the contact between universities and enterprises is thus first established in informal networks through people knowing each other from private or family contexts, as alumni or graduates of the university, as former colleagues or business partners (described in some detail in, e.g., Carayol 2003; Thune 2006). Only later those ephemeral contacts may develop into loose co-operations or even to different degrees of institutionalisation. While institutional framework conditions play an important mediating role as a factor channelling and enabling action and encounter, the motivation, goals and communicative capabilities of the *individual actors* in question are the key drivers of the process. In any case, the framework conditions that may have shaped the first meeting of actors are in most cases quite different from those that later become relevant for the decision about or the further development of a co-operation.

Motivation and personal goals are thus the initial creators of momentum at the beginning of the process. While certainly bearing the imprint of framework conditions, they are an independent driving force with individually distinctive characteristics. The impact of framework conditions, on the contrary, is contingent on the form of action taken or planned. Conditions that are enabling for a certain type of endeavour may well be obstructive for another. Nonetheless, communicative capabilities as well as material, human and social resources are important framework conditions that modify the outcome of similarly motivated actors and therefore need to be taken into account (as demonstrated for spin-offs by Kroll 2009).

With regard to personal factors, the more independent factors of individual motivation and the more inclusive set of personal characteristics such as experiences and norms will be subsumed under one label ("personal factors") to avoid the creation of an overly complex model. It should, however, be borne in mind that personal characteristics can be both creators of momentum (e.g., entrepreneurial decisions) and filters of action (e.g., decision not to interact due to bad experiences).

In short, in the course of this chapter we will attempt to differentiate the very coarse model sketched in Fig. 8.1 and give it a temporal dimension later in Fig. 8.2.

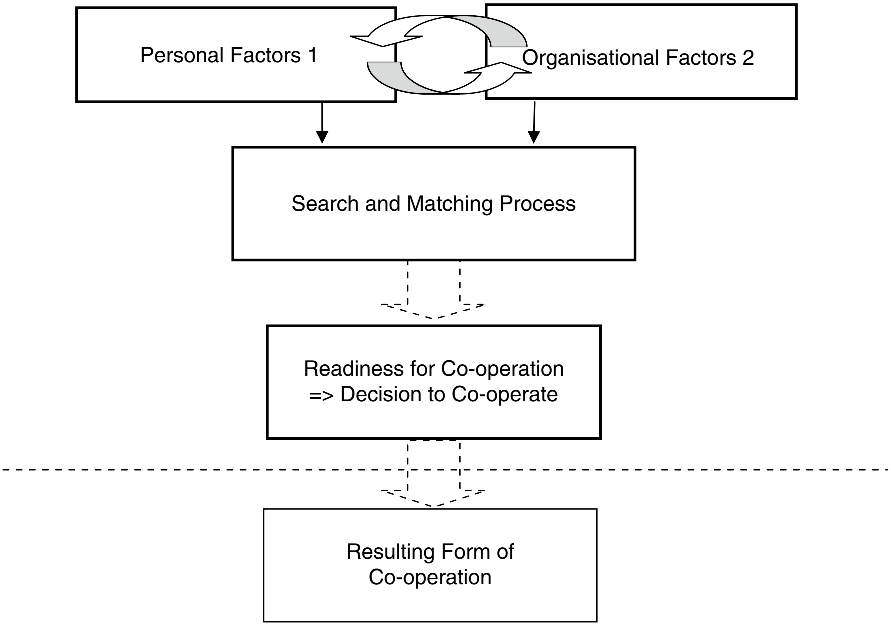

Fig. 8.1 A stepwise approach to the determinants of science–industry co-operation. Source: own figure

8.3.2 *Factors of Influence*

The establishment of SIC can be conceptualised as a process determined by several steps and by a number of main and subordinated factors. Literature has shown that a large number of potential factors of influence can be distinguished and, according to the general nature of the approach, there are many logics for groupings and typologies (see, e.g., Backes-Gellner et al. 2005; Thune 2006; Schartinger et al. 2002; van Horne et al. 2008; Carayol 2003). The first challenge will, therefore, be to reduce complexity by subsuming known factors into a limited number of principal categories. Following the logic sketched above, we will differentiate factors related to the individual actor (the actual people initiating the collaboration) from factors associated to the organisation (the company or university they are acting for or at least are organisationally attached to). Beyond the abovementioned theoretical tenets, this is based on the assumption that, when discussing innovative-minded dynamic researchers, it appears highly artificial and counterintuitive to exclude personal factors from the logic of a typology. Consequently, we will assume that personal factors may play the key determining factor for the process to enter into

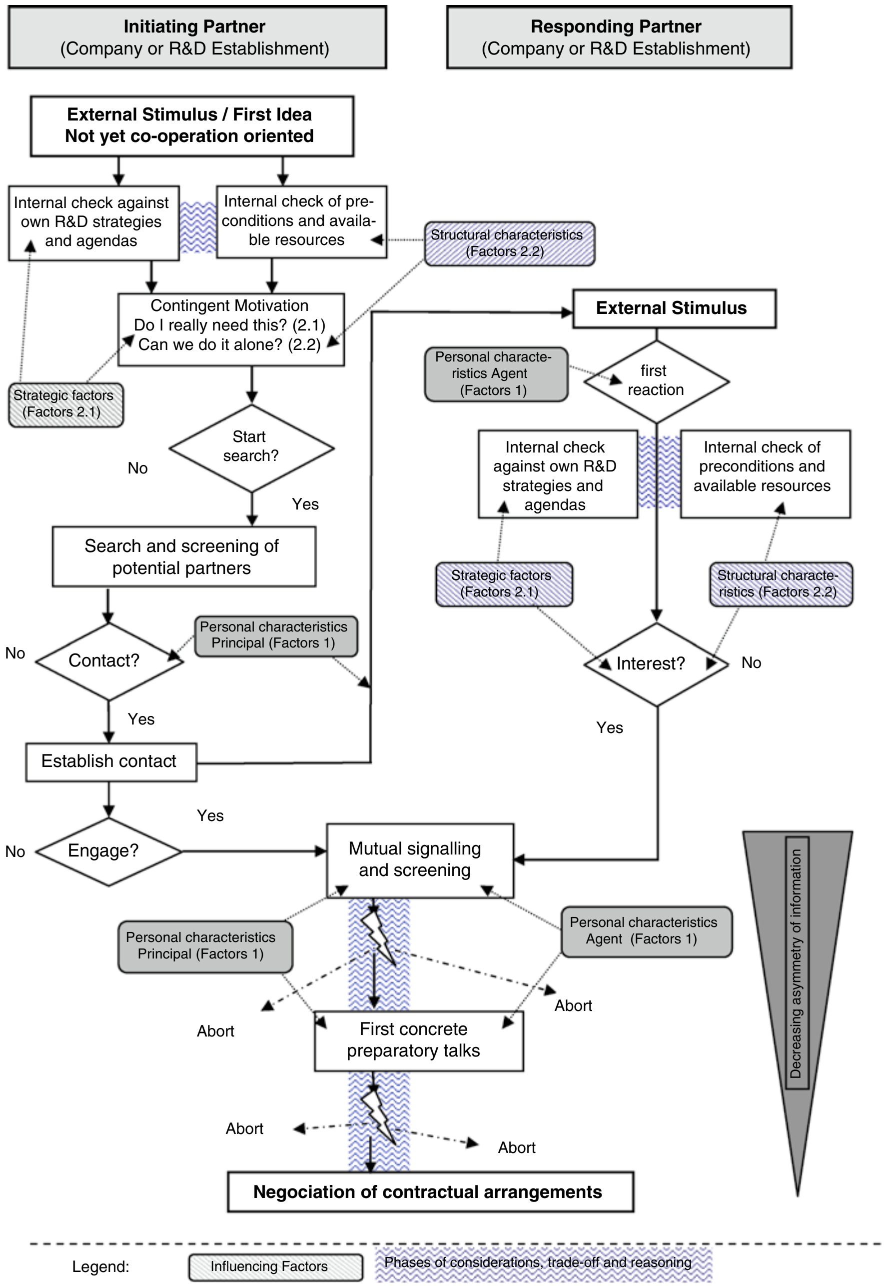

Fig. 8.2 The searching and matching process

R&D collaborations. Even the most dynamic actors, however, act under institutional constraints that are difficult to override. Organisational factors thus provide the second side of the picture. In short, as a result of our literature review, we suggest the following categories of factors:

Factor category 1: Personal characteristics

Static factors (long term)

- Formal qualification or training (profession).
- Past professional experiences and curriculum.
- Communicative capabilities and other soft skills.
- Social competences.
- Co-operation experiences in the past.
- Individual set-up of success criteria.
- General personal priorities and general personal goals.

Dynamic factors (short term)

- Current personal priorities, current personal goals.
- Distinct motivation with regard to the particular co-operation planned.

Factor category 2: Organisational characteristics

Strategy (factors 2.1)

- Type of strategies.
- Technological field of activity.
- Type of R&D needs (e.g., basic or applied research, consultancy, development, etc.).
- Timing of research work, expectations of duration.
- Disclosure behaviour and collaborative openness.

Structure (factors 2.2)

- Available financial resources.
- Available and equivalently qualified work force.
- Available infrastructure (labs, devices, etc.).
- Absorptive capabilities.
- Cooperation experiences in the past.
- Signals (on capabilities, reputation, status or performance, etc.).

In the following sections, we will – for each of the above factor categories – briefly review what can be learnt from existing literature. Additionally, we will complement these findings with concrete evidence from Fraunhofer ISI's practical experiences in applied research and evaluation. Due to the nature of the reports available, information will mostly be taken from summaries and conclusions and can thus not directly reflect individual interviews. Also, due to the continued confidentiality of some of the reports, data have to remain anonymised.

In detail, the basis of our experiences which we used to mirror with existing literature are reports and internal documents from:

- An evaluation of German support measures for industry co-operation with universities of applied sciences (cf. BMBF 2008).
- A support program for regional clusters (Bührer et al. 2008), three studies on technology transfer between research institutions and industry (Hemer et al. 2006, 2007, and 2010).
- One study on traditional and modern forms organising university–industry co-operation in Germany (cf. Koschatzky et al. 2008).
- Studies on university–company interaction in various contexts.
- Evidence from those reports will provide us with concrete examples for the ways in which both personal and organisational factors have an impact on the process of establishment of co-operations, which we will then summarise in a model that is much more differentiated than that which can be derived from the broad conceptual considerations sketched above (Fig. 8.1).

8.4 Brief Illustration of Relevant Personal and Organisational Factors

8.4.1 Personal Characteristics[4]

Cooperations are initiated and carried out by individuals rather than by institutions. Our practical work shows that it depends largely on these persons' motives and characteristics whether R&D collaborations are initiated or not. It is common sense that a large number of factors are related with these individual characteristics. Among them we regard formal qualification or formation (i.e., the person's profession), his past professional experiences and career, his temper, health and mental set-up, his communicative capabilities and other "soft skills", his social competences and, last but not least, his co-operation experiences in the past as some of the important characteristics relevant for the willingness and readiness to consider research co-operation with other organisations.

Researchers acting in directive roles within their organisations strongly determine their absorptive capabilities and their internal set-up towards heterogeneous R&D collaboration. Through this, the individual characteristics are being converted into behavioural characteristics of their research unit. Empirical evidence suggests that the ability to build lasting co-operation between a university and a company depends on a number of "soft", experience-based criteria like the industrial R&D

[4] The statements in the following sections stem from various sources including own observations and are not referenced individually in all cases.

manager's familiarity with an academic working culture, preexisting experiences with collaborations with universities, concerns about confidentiality, and many more. These criteria are in parts strong barriers to enter into collaborations and they may determine the process of development of SIC much more than rational or economic considerations (see, e.g., BMBF 2004:136, 2008:44–49).

Many SMEs that could in practice benefit quite a lot from co-operation with universities and vice versa feel a natural emotional distance to the partner's working style that is only overcome if a concrete, useful offer is communicated to them in the right way. In many cases, some sort of common external catalyst will be needed to kick-start a collaborative effort. Alternatively, prior personal acquaintance can serve as the basis of such activities (cf. BMBF 2008). Unsurprisingly, therefore, there is a lot of empirical evidence that science–industry collaboration suffers from the difference of working styles and the difficulty to understand each others' objectives and motives, working conditions and community language as well as technical and financial restrictions. Certainly, a large number of projects have not been realised because of such factors, although the financial, technical and scientific prerequisites were given and there was a general will to cooperate.

Undoubtedly, the willingness to consider R&D collaboration with partners from different sectors also strongly depends on the individual actors' personal motivation and goals' structure, i.e., on factors that, other than the more static long-term factors discussed above, can change rapidly and are not always easily discernible from the outside. By saying this, we mean individual, not necessarily rational, intrinsic and also extrinsic motives rather than purely carrier motives, economic or rational goals which often might only be adopted from the goals set by the employer. Scientific literature surprisingly often reduces motivations to results of rational reasoning (cf. Carayol 2003) ignoring the strength of nonrational motives and everybody's own empirical evidence that they may well override supposedly stronger rationales.

Of course, nonrational individual motives are closely connected to and determined by individual personal characteristics of psychological, mental, social, and physical nature so that it is not arguable that two persons of same age and providence, formal qualifications, similar careers, and other hard characteristics, working in similar or identical environments under equal conditions, would develop different personal priorities with respect to seeking R&D co-operation.

However, as most individuals will at least partially adapt their personal motivation and goal system to that of their social and working environment or to that of their peers, we observed in our projects the emergence or existence of certain *motivation stereotypes* in specific social or professional groups such as university teachers or R&D workers in companies. In other words, such "motivation stereotypes" can, on the one hand, be identified and, on the other, be associated to the employing organisation's general goals structure. For instance, when in recent years most *university professors* have become increasingly exposed to the need to acquire third–party funding, the importance of science–industry collaborations as an element of departmental strategies has risen. Many professors see co-operations with industry as a vessel both to acquire additional funding from private sources and to generate more leeway to shape the research strategy of their department. This is an example of how external factors of influence common to a homogeneous group of peers can build a system of common extrinsic motives. Moreover, as research is mostly performed in groups, their motivation stereotypes might easily convert into those of the faculty. Etzkowitz (2003) mentioned this in the context of university researchers' attitudes. On the other hand, industrial research contracts, particularly when performed by independent institutes attached to universities, can indeed be a source of substantial additional personal income for university professors and, thus, becoming an element in the individual motives' structure.

8.4.2 Organisational Characteristics

8.4.2.1 Strategy

The term "strategy" is closely related to "goals", "aims" or "objectives" and everyday experiences often show that these terms are used synonymously, although a theoretical differentiation may well exist (see, for instance, Götze and Mikus 1999:14–18; Pleschak and Sabisch 1996:57–68). Strategies denote medium or long-term ways or instruments to achieve one's goals. As mentioned above, objectives behind an intention to seek research collaboration differ between the potential partners, so will, consequently, do the strategies. One could also state that this is a constitutive characteristic of heterogeneous co-operations due to the partners' different roles in their innovation system. Freeman (1987) and Hall (1999) even claimed that there is a fundamental conflict between those motives typical for the research system and those typical for the industrial system, leading to inevitable tensions between the two. Joint research and innovation activities of public research institutions and industry are largely influenced by their individual hierarchy of objectives, as well as by their self-image and that of their stakeholders.

The literature review has revealed a great number of goals and objectives that the different types of organisations seeking collaboration typically express and many empirical data on that have been processed (cf., e.g., van Horne et al. 2008; Carayol 2003; Schartinger et al. 2002; Thune 2006; Bonaccorsi and Piccaluga 1994). However, the papers relate to different theoretical backgrounds and apply different methodological approaches, use data and samples of unequal quality, and follow various research intentions. Thus, a consolidated and concise conclusion or classification of the organisations' goals can not yet be given. For the sake of this chapter, we simplify the situation by consolidating all possible goals into one and the same group of factors under the factor category 1 and comment on only some selected aspects which we could observe during our own explorative work.

For *research institutions and universities* with an agenda that is particularly focused on applied research, co-operations with industrial enterprises also constitute an opportunity to gain reputation by demonstrating the practical utility of their research results, raising their visibility, and improving their networks in the industrial community. Additionally, experiences gained in applied research can help professors to develop or improve curricula and to arrange internships for students planning to work in the private sector.

For *small and medium-sized enterprises*, the search for partners often involves the desire to remain competitive under changing framework conditions. Additionally, SMEs may get help from universities to cope with a diffuse perception of "falling behind", to conceptionally focus their needs and to develop and sharpen their technological profile. Often, they do not know exactly "what they want" but rather "which problem to solve". They are often looking at science–industry collaboration as a possibility to access technological competences that would be difficult or too costly to develop in-house and to delegate technical risks that they feel ill-prepared to handle themselves (see Koschatzky et al. 2008:109). Very often, they also aim to develop a necessary critical mass in terms of personnel working on a larger project.

In contrast to SMEs, *large companies* with significant own R&D capabilities often aim to access very specific competences of universities and research institutions, either to compensate for competences they lack or to reduce their own research teams and equipment. These are deliberate strategies either to achieve their research agendas or to save research expenditures by means of externalisation. This holds particularly true for any type of research that is still rather far from a specific product development, i.e., basic research and basic applied research. Their motivation to pay for this sort of externalised R&D is that they have realised that public research institutions can perform certain types of research cheaper, better, or quicker than their in-house teams.

Both types of companies (SMEs and large ones) occasionally use university collaborations as a means for headhunting for graduates. In our empirical evidence, however, this aim is found somewhat less frequent than one would expect, at least as a main driver of motivation.

8.4.2.2 Structural Characteristics

As a tendency, co-operations can emerge when research results developed at the research institution appear relevant for enterprises and to bear a potential of applicability. The research partners thus have to command relevant and sufficient capabilities and capacities. Evidence from the evaluation of co-operative projects of universities of applied science demonstrates that some large enterprises employ "scouts" for exactly the reason that co-operation partners with the necessary competences are difficult to find.

On the other hand, as other authors have elaborated in the context of the term "absorptive capacity" (e.g., Cohen and Levinthal 1990), the industrial partners need certain amounts of technological capabilities and human resources of their own, so that they are able to absorb the knowledge flowing between the co-operation partners. Small firms may have the equipment and, at times, even the financial means necessary to conduct research but lack the appropriately qualified personnel, which they hope to access via co-operation with universities.

8.5 Summary: Towards a Conceptual Approach for the Establishment of Science–Industry Co-operations

Summing up, a number of factors (both personal and organisational) have been identified which mutually influence each other and jointly impact on the process of establishing a co-operation as sketched in Fig. 8.1.

On the basis of the findings of this chapter, we have developed a conceptual model for the preparatory and early stages of the process of a bilateral R&D collaboration between an initiating and a responding partner (Fig. 8.2). The flow chart illustrates that the establishment of a co-operation has to be conceptualised as a step-wise interactive process during which both organisational *and* personal factors alternately or simultaneously influence the decisions taken, implying that both subjective and objective or rational criteria are at work.

Additionally, Fig. 8.2 clarifies a key issue with regard to the establishment of SIC, which is often overlooked: that the first steps in the process are taken before the co-operation is even thought about: It is a key finding of our empirical review that the majority of processes of co-operation are not originally developed in a co-operative manner; instead, an external stimulus motivates one partner to develop a motivation for co-operation which he then proposes to another. At first, the initiating partner often merely considers his own situation and only in the process learns about the personal and organisational characteristics of his counterpart. To a degree, this situation resembles a principal–agent situation (cf. Jensen and Meckling 1976).

The key actors at the organisation in question take the first relevant steps far before the first directed contact is made. At some point in time, there is an external stimulus that motivates them to think about a certain issue which they then evaluate in the light of the organisation's strategy (do we need or want to solve it?) and the organisation's resources (can we handle it alone?). Only if at that point they come to the conclusion that co-operation might be a solution to handle that particular issue, their initial motivation is finally formed – by the organisational framework of their institutions.

The external stimulus triggering this process of thinking can be manifold, e.g., a casual contact at a conference, the market pressure upon a company to develop a new technology or product, or the political pressure on universities to patent and financially exploit technologies they develop. Different players in the innovation system are thus typically differently motivated and follow different objectives to start with (cf. BMBF 2004:129–147; Koschatzky et al. 2003:26–27; 2008:107–110; Lee 2000). Additionally, however, and just as important, their original motivation is transformed by their differing strategies and structures in a second step (lest the external pressure should directly require co-operation for its own sake).

Following the consideration of the relevant internal organisational characteristics, the initiating partner decides whether to search for partners or not, a decision, which – at this point – can possibly be captured by rational choice criteria (Carayol 2003). Whether, however, he then decides to establish contacts in individual cases that appear relevant according to such criteria and how he goes about doing so will, to a high extent, be determined by the mentioned broader array of personal characteristics, which go beyond mere rationality.

For the second partner, the process only starts when concrete contact is made. Other than the first, he is confronted with a direct request for co-operation (not the perception of an issue) which he can evaluate against his organisation's strategies and internal resources. On his part, there is thus no initial motivation, but a reaction to a request. Again, much in this process will depend on his personal inclination to consider the request and his communicative ability to deal with it. Likewise, he makes a clear-cut assessment of the balance of expected risks and benefits and the opportunity costs of not collaborating, since his motivation, in the first step, is reactive.

Finally, if both partners agree to engage, the initial asymmetry will gradually fade away. Both are now actively working towards concrete agreements for their mutual benefit. If the process in the first steps has been diligently performed, all organisational factors are by now known and assessed, whereas the personal level attains a key role. What remains are asymmetries regarding scientific or technological knowledge. At this point, the key actors must find a way of actually working together. If this fails, the whole venture will have to be aborted, even if all organisational factors suggest that it would be beneficial and the original motivation was there.

It is important to stress that the individual steps displayed in Fig. 8.2 may, in reality, happen implicitly or unconsciously or be shortened to a pragmatic and brief action. Also, the interactive process may in reality be much more complex due to iterative loops that emerge when screening and assessments at the early stages are not carried out diligently or when organisational conditions change in the course of the process.

In summary, evidence shows that the notion of the assessment and ranking of partners ("assortative matching") introduced by Becker (1973) has to be called into question. In practice, partners in SIC are hardly chosen according to strict rational choice criteria, but according to personal and organisational characteristics in an interactive process as outlined here. Even if rational choice was a more prevalent factor than evidence suggests, "assortative matching" could only be instrumental in describing the beginning of a far more complex process. We maintain that there is no rationale as we know from "microeconomics of science–industry collaboration" (Carayol 2003) but, rather, an institution-dependent sequence of actions which in the end entails the creation of new organisational set-ups or institutions that could much better be captured by conceptual notions from sociology and possibly psychology (e.g., Scharpf 1997).

8.6 Conclusions and Outlook

The approach developed in this chapter is a first conceptual template to address aspects of the foundation and early stages of an R&D science–industry collaboration – an issue that has not yet intensely been dealt with. In summary, the following claims have been developed from a review of available literature and own empirical observations:

First, a broad, inclusive array of personal characteristics is central to the process of the establishment of R&D co-operations. A mere institutional or rational choice-based approach will thus necessarily be insufficient to explain and structure the complexity of the processes observed. Organisational factors are, however, important as they shape the consequence of personal considerations at an early stage of the process (and possibly later).

Second, based on anecdotal evidence, this chapter has developed a conceptual framework for co-operations which are started in an asymmetric manner. A review of empirical work performed by the authors has suggested that this is more often the case than usually accounted for. In a situation where an initiating organisation develops the original momentum to seek R&D co-operation, the potential partner organisation is approached with the concrete (more or less elaborated) proposal to co-operate so that his process of assessment takes place against a different background. This indicates clearly the necessity for a more differentiated approach when investigating the early initiating steps of research partnerships. Our findings consequently imply that the organisational form, type, or characteristics of the R&D partnerships, which are finally established at the end of this process, must be affected by – a priori – two independent sets of organisational and personal factors on the sides of the two research partners.

It is clear that this chapter has taken but a first step to shed light into what so far largely is a black box. It has succeeded, however, in providing a conceptual model as a point of departure that allows us to structure future research. This model has been based on a "summary of summaries" of next to a decade of empirical work. We demonstrated that a model can be meaningfully developed on that basis, but do not dispute that, with regard to its empirical validation, there is a limit to what can be extracted from existing reports. To corroborate the validity of or to modify the suggested role of individual steps, further empirical research "on the ground" will be needed.

Finally, based on our key findings, we regard the following research tasks as worthwhile to deepen the understanding of the process of seeking and establishing SICs:

1. To release the assumption of general validity and to try to elicit technology-specific processes of establishment of SICs.
2. To check whether all relevant personal and organisational factors have been included and, if not, add others to the catalogue.
3. to specify in more detail the ways how personal characteristics have an impact at the different stages of the process and provide concrete examples.
4. To explain in more detail and empirically check if the screening process for potential partners can actually be described by rational choice criteria.
5. To develop a typology of failures at different stages in order to establish a model of critical thresholds like those, for instance, known from the literature on spin-offs.

6. To trace further steps in the process of entering into a research partnership and to identify the factors determining specific forms and types of SICs (see Fig. 8.1).

Finally, the key claim that co-operations tend to start asymmetrical and – if at all – only later become less so has to be corroborated by broader evidence. It remains to be seen if the model is robust to broader empirical testing.

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Chapter 9
Turning from Laggard to Leader in National Radical Innovation and Beyond

The Case of Mannesmann's Predevelopment Unit and the Project Robin for Germany's Electronic GPS-Based Truck Toll System

Stefan Hüsig

9.1 Introduction

It is well received that technological and social innovations are important drivers for the growth and prosperity of single nations, regions, and beyond (Mensch 1975; Nelson 1993; Romer 1996). However, not all innovations are born equal. In the broadest sense, most scholars distinguish innovations into incremental and radical types, the latter being the more difficult and desirable to archive. Radical innovation on the firm level is fundamental to business rejuvenation and growth and critical to company survival in the long run (Leifer et al. 2000; Christensen and Raynor 2003; Tushman and O'Reilly 1996; Utterback 1994). Incremental innovation and cost-cutting measures alone are not sufficient to sustain company growth and prosperity. However, the understanding and measurement of radical innovation by different authors are often unclear and not consistent (Daneels and Kleinschmidt 2001; Hauschildt and Salomo 2005; Gatignon et al. 2002; Garcia and Calantone 2002). Previous research on radical innovation has resulted in a variety of typologies, such as radical, disruptive, competence destroying, architectural, discontinuous, or really new innovations (Hüsig 2006; Garcia and Calantone 2002; Gatignon et al. 2002). Although these definitions of innovation types have resulted in a clearer understanding of each defined innovation area, they have also created confusion among academics and practitioners. There is no homogeneous concept or categorization of radical innovation, and terms such as "disruptive" and "radical" innovation are used interchangeably (Hüsig et al. 2005; Hüsig 2006). Although many concepts share common characteristics, they also reveal important differences that have often not been sufficiently differentiated in the literature.

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One of these frequently overlooked aspects in the existing frameworks on innovativeness is the perspective of the country level as a major entity of institutional contexts, policies, and regulations. Typically, innovation processes or projects are studied at the firm level as micro- level and at a macro- level perspective, where innovativeness is evaluated based on factors exogenous to the firm, such as familiarity of the innovation project to the world, market, or industry (Garcia and Calantone 2002; Daneels and Kleinschmidt 2001). Spatial or institutional aspects were usually neglected in the innovativeness measurement and related frameworks in the new product development (NPD) literature. However, this reductionist view might have some limitations. The national or supranational (e.g., EU) contexts are frequently subject to major policy and regulatory activities which might create significant differences for the management of radical innovation on firm and industry levels. This might be especially relevant in terms of (de)regulation or other governmental influence in industries such as telecommunication, defense, pharmaceuticals, or finance. Additionally, politically implemented incentives or regulations directly supporting innovation financing, activities, and intellectual property tend to differ in various countries. Countries often have unique institutional features in relation to other countries; therefore, it is quite possible that factors associated with effective managerial responses to radical innovation in one country may not apply in other contexts (Chesbrough 2003). Finally, the conceptionalization of the degree of innovativeness itself also depends on the relative newness and diffusion of the innovation, which is typically subdivided into broad contexts such as new to the firm, industry, or world (Garcia and Calantone 2002; Hüsig 2006). Although the national context is often perceived as losing relevance due to increasing globalization and integration of regions and the world economy, this perception might be too simplistic and not universally true for innovation processes in all industries and regions. Recently, the national context received increased attention due to the new innovation policy of China which calls for "independent innovation" which is specifically targeting the development of domestically developed innovations (Kai 2006).

The research questions to target in this chapter are

- How radical innovation at the national level can be conceptualized?
- Which role the national and supranational institutional factors play?
- What success factors exist at the firm and project level?
- How these kinds of innovation projects or processes take shape?

Therefore, this chapter takes a closer look at an innovation process where the specific national and supranational context played a decisive role in the development of a new product, and service and market combination that represented a novelty especially at the national level: A new high-tech system for electronic road tolling in Germany. Since road tolling is a typically locally based market with characteristics of infrastructure, it seems to be especially sensitive to the country context. This case study describes and analyzes the rise of a late entrant in the area of electronic road tolling systems – Mannesmann AG – from a laggard nation without an initial regulation for road tolling since road infrastructure was traditionally financed by the government without costs for the users – Germany – in the traditional market of road tolling equipment which was before dominated by a number of established foreign incumbents with conventional technology. By faster anticipating and combining previously unrelated trends in the technological, institutional, and market domains, plus transforming them into a new radical approach by their predevelopment unit, the once lagging company managed to introduce the core of the new high-tech system for electronic road tolling in Germany – the so-called "onboard-unit." The case illustrates how a new entrant firm from a laggard national context had to face institutional resistance and political uncertainties due to its seemingly unfavorable national context conditions and managed to turn into a technological and national leader position. Therefore, this case represents an extreme case of a specific type of innovation where novel technologies are combined to address a new application in an emerging market at the level of the national context – namely "national radical innovation" (NRI).

This chapter is structured in the conceptual and theoretical framework, the case study of Mannesmann's predevelopment unit and the project Robin for Germany's electronic GPS-based truck toll system and finalized by theoretical implications as well as propositions for future research.

9.2 National Radical Innovation: Conceptual and Theoretical Framework

9.2.1 The NRI Concept as Part of a Holistic Categorization Scheme for Radical Innovation

The basic prerequisite for categorizing and measuring innovativeness of radical innovation is a clear understanding of the complex and multidimensional concept of innovation. Typically, innovation should be seen from different perspectives (Hüsig 2006; Hauschildt 2004; Garcia and Calantone 2002):

- Content/object dimension: What is new? e.g., regarding technologies, structures, markets, culture, institutions, strategies, systems, products, services, components, resources, etc.
- Intensity dimension: How new? The innovativeness of the innovation, however measured.
- Context/subjective dimension: New for whom, seen from which point of reference? Person, organization, firm, domain, resource base, industry, market, nation, world, etc.
- Process dimension: When and where does the innovation process start and end?
- Normative dimension: When is an innovation successful or unsuccessful?

However, innovations have too frequently been treated as uni- or bi-dimensional phenomena, with labeling or definition of these dimensions being inconsistent (Garcia and Calantone 2002). Therefore, researchers continue to lack a general descriptive framework and opportunities for cross-case and cumulative research are hampered. With regard to the multidimensional nature of the innovation phenomenon, innovation can be defined as…

> … an iterative, interactive, context-specific, multi-activity, uncertain, path-dependent process and the result of a new combination of ends and means from a certain perspective. From that perspective, someone must perceive a difference concerning the qualitative newness of an object compared to a prior status in a given context. This new combination must be introduced into a specific context which is the point of reference of the prior status.

This definition of innovation is used to develop a better understanding of the degree of innovativeness in the case of technological innovation processes in the firm domain over certain points in their life cycle (*concept, realization,* and *impact*). Technological innovation processes embody inventions from industrial arts, engineering, applied sciences, and/or pure sciences (Garcia and Calantone 2002). Here, the degree of innovativeness consists primarily of criteria of the intensity, context, and normative dimensions of innovation. The criteria of the content/object dimension serve as points of reference to compare the innovation projects to a specific status *ex ante* in a given context. To add the dynamic aspect, the process dimension defines the phases in which the degree of innovativeness is evaluated since empirical research from case studies on radical innovation processes demonstrates that the outcomes of innovative concepts are often not equally distributed or stable (Lynn et al. 1996; Leifer et al. 2000; Hüsig 2006). Because of the high and long-term uncertainty of radical innovation processes, the degree of newness over the multiple dimensions of innovation often changes during the evolution of the project. This means that it is not sufficient to measure innovativeness of radical innovation projects at only one point in time.

Furthermore, categorizations of radical innovation typically focus on performance criteria which describe results or the impact of the innovation process, such as those of Leifer et al. (2000), Christensen (1997), or Foster (1986). However, performance measurement is rather normative, in itself context related and at best only known with certainty at the end of the process. In isolation, performance measurement is not compatible with the degree of innovativeness, defined here as newness. Due to mixing measurements of performance and innovativeness, many radical innovation projects and processes remain invisible for research in the front end or are attributed incorrectly to poorly managed incremental innovation projects, as the implementation of conventional measurement methods and definitions of radical innovation does not take into account projects which have not yet come to fruition, which have been changed, are unsuccessful, or where not all aspects are radical. Therefore, concerning the degrees of innovativeness we distinguish between concept, realization, and impact, which is a perspective on innovativeness measurement that has been largely ignored in prior approaches. Including the process dimension in the innovativeness measurement framework allows for a study of path-dependent changes in the degree of innovativeness at the project level.

I understand the term *concept* as the result of the front end of the innovation process, which is usually a kind of project plan or product concept including the basic technological and business rationale. It could be seen as the result of the definition process for the content dimension of innovation as described by Burgelman and Sayles (1986) or Bower (1970). This is where the intended strategy for the innovation project is formulated (Christensen and Raynor 2003). *Realization* represents the outcome of a radical innovation project concept – the realized strategy – which is often not the same as the formulated plan (Christensen and Raynor 2003; Leifer et al. 2000). As a result, in this subsequent phase of the innovation process different degrees of innovativeness could also emerge, which should be measured using an adequate method. The *impact* of the innovation project is defined normatively as performance and success dimension *ex post*. This step-by-step measurement enables our framework to evaluate the innovativeness dynamically over the major stages of the innovation life cycle.

In the context/subjective dimension, I use both a *macro-* and a *micro-*perspective in modeling the project innovativeness construct, as Garcia and Calantone (2002) suggested. The distinction between macro- and micro-perspectives is important as it identifies to whom and from whose perspective the innovation is new. The micro-perspective typically views innovativeness as being new to the firm or new to the firm's customers (Garcia and Calantone 2002; Daneels and Kleinschmidt 2001). The innovation project can include aspects which are new to the firm's marketing or technological capabilities or aim at domains or industries which the firm has not yet tapped. The innovativeness of an innovation project is contingent upon the firm's capabilities and competencies.

Therefore, I distinguish a *microlevel perspective* which views innovativeness as new to the *firm* and includes technological, market, organizational, and industry factors in the content/object dimension. While all state-of-the-art multidimensional frameworks for evaluating the degree of innovativeness have technological and market factors included, it is less common to take organizational and industry factors into account. Industry factors indicate whether the innovation project targets competitors, consumers, complementors, cooperation partners, or suppliers new to the firm. According to the market-based view (Porter 1980, 1985, 1991), the newness of a targeted industry for a firm should also indicate higher project innovativeness for the firm. Organizational factors (changes in structures, processes, and culture that are new to the firm) are integrated as the result of innovation project concepts and are therefore excluded at the *concept* stage at the firm level.

From a *macro-level perspective*, innovativeness is evaluated based on factors exogenous to the firm, such as familiarity of the innovation project to the world, market, or industry (Garcia and Calantone 2002). In this framework, the point of reference at the macro-level is subdivided into *industry*, *nation*, and *world*. Even though most scholars do not split the macro-level context into different entities, I think this might oversimplify the reality too much and unnecessarily reduce the explanation power of the innovativeness construct. To illustrate the significance of the subdivision at this level, two examples might be helpful: In the case of radical or disruptive innovations, technologies from other industries are frequently used to disrupt or substitute the incumbent firms and products, although the applied technologies themselves are not new, or are not applied to the world at all but only to the disrupted industry (Christensen and Raynor 2003; Leifer et al. 2000; Hüsig 2006). Disruptive technologies such as MP3 or digital imaging did not originate in the music retail or photofinishing industry, and neither were they first applied here. These technologies and applications typically come from domains outside the threatened industry. The context-level nation plays an important role for institutional, regulatory, and infrastructure factors which are relevant for innovation projects and their relative degree of innovativeness (Hüsig 2006). Technological and market factors are relevant for all context levels from the macro-perspective.

Furthermore, an additional distinction between *familiarity* and *fit* is made in the context of innovativeness measurement, as Daneels and Kleinschmidt (2001) pointed out. The "newness" as familiarity conceptualization draws on organizational theory regarding the relationship between the organization and its environment, since innovation projects may enlarge the domain of the organization, and, depending on the extent to which they do so, confront the organization with an unfamiliar domain (Daneels and Kleinschmidt 2001). The less well known a part of the environment is, the more *unfamiliar* is the domain and the higher the degree of innovativeness of the innovation project if it targets such an unfamiliar domain. This concept of newness is used in all context/subjective and content/object dimensions in this framework, except for the organizational factors at the firm level and the institutional factors at the national level in the realization stage. In these cases, I framed newness as fit, which is another way of looking at the notion of newness to the firm or nation. For this conceptualization I draw on the resource-based view (e.g., Barney 1991), which was often used in the innovation literature to express the need for changes an innovation project potentially or effectively causes in the resource base of the chosen context (Leonard-Barton 1992; Daneels and Kleinschmidt 2001). For example, the fit (often also framed as "synergy") of an innovation project with a firm context refers to how well the internally available resources fit the requirements of a new product project, that is, the extent to which the new product fits with the firm's resources and capabilities (Daneels and Kleinschmidt 2001). For my framework, this conceptualization of newness was defined as *need to change* with regard to the technological and market factors at the firm level in the concept and realization stage, and concerning the organizational factors at the firm level and the institutional factors at the national level in the realization stage. An overview of the structure of the concept and the realization stages of our innovativeness framework is given in Fig. 9.1.

Based on this dynamic and holistic framework for the measurement of innovativeness, new categories of radical innovation projects are developed. So far, many radical innovation (RI) concepts are based on performance measurement *ex post* and do not consider the newness aspects or take them more or less for granted, regardless of the context. On the other hand, there is a consensus that radical innovation can be separated from incremental innovation if a discontinuity occurs simultaneously in the technological and the market domains in a given frame of reference (Daneels and Kleinschmidt 2001; Hüsig 2006). I build on this consensus and distinguish radical from incremental innovation projects if they represent *simultaneously*

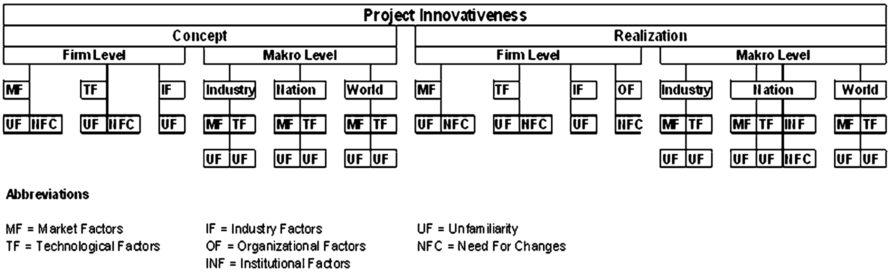

Fig. 9.1 Structure of concept and realization stages of the innovativeness framework

new combinations of technological and market discontinuities in a given context at a given stage in the innovation process. If this concept of RI is combined with our dynamic innovativeness framework, we can define different RI project subtypes in the context and process dimensions. In the process dimension, the following RI project subtypes can be defined:

- *Radical concept* is defined as a new combination of technological and market discontinuities simultaneously aimed at in the stage of an innovation project concept.
- *Radical realization* is defined as a new combination of technological and market discontinuities simultaneously implemented in the stage of an innovation project realization.
- *Radical impact* is defined as a combination of technological and market success simultaneously achieved by an innovation project from an *ex post* perspective.

Some RI project subtypes can also be defined in the context dimension:

- *Firm-level radical* is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, or achieved by an innovation project in the context of the firm.
- *Industry-level radical* is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, or achieved by an innovation project in the context of the industry.
- *Nation-level radical* is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, or achieved by an innovation project in the context of the nation.
- *Global radical* is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, or achieved by an innovation project in the context of the world.

The *total project-radicalness matrix* presents these RI project subtypes in combination and provides an overview of possible characteristic of innovation projects in Fig. 9.2. The matrix enables a more comprehensive categorization of innovation projects and allows for variation in the degree of radicalness depending on the stage

Fig. 9.2 Total project-radicalness matrix

		RI Process Subtypes		
		Radical Concept	*Radical Realization*	*Radical Impact*
RI Context Subtypes	*Firm Level Radical*			
	Industry Level Radical			
	Nation Level Radical			
	Global Radical			

and context of the innovation process. This step-by-step and context-dependent categorization enables researchers and managers to evaluate the innovativeness of an innovation project dynamically over the major stages of the innovation life cycle. Using this framework, NRI is understood as a specific type of RI, which is analog to the RI context subtype of *nation-level radical*. NRI is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, and achieved by an innovation project in the context of the nation. This framework is used to analyze the innovation process in the case study later on.

9.2.2 Preliminary NRI Framework

Based on established models of the RI process by Veryzer (1998), Reid and Brentani (2004), Leifer et al. (2000), and Lynn et al. (1996), a preliminary theoretical framework for the NRI process is developed. The RI model by Veryzer (1998) is chosen as a model for the RI process on the firm and project level – the innovativeness of the analyzed projects on which this model was built corresponds approximately with the RI context subtype *firm-level radical* in the total project-radicalness matrix above. This model is complemented by the *probe-and-learn*-model by Lynn et al. (1996), which integrates also macro and institutional context factors and Reid and Brentani (2004) who provide a deeper look into the various actor roles of the process and its boundaries. The dynamics of discontinuity are explained at the macro-level by frameworks of Teece (1986), Abernathy and

Utterback (1978), and Tushman and Anderson (1986). The NRI framework combines the various context levels and the RI frameworks into a holistic framework to describe and explain the major stages and influencing factors on different context levels.

At the *macro*-level, which is defined here as *industry*, *nation*, and *world*, various sources of supportive or inhibiting factors for RI exist. As research shows, discontinuities in markets or technologies provide external influences that can be framed as opportunity or threat on the firm level (Christensen and Raynor 2003; Abernathy and Utterback 1978; Tushman and Anderson 1986; Gilbert 2005). Especially the study by Lynn et al. (1996) has shown how these discontinuities affect the RI processes in firms to cope with such high degrees of uncertainty. However, for NRI, another, so far less researched source of uncertainty might be an important factor for RI, such as institutional or regulatory discontinuities originating from national or supranational entities. Therefore, the following proposition is developed:

Proposition 1: *Institutional or regulatory discontinuities originating from national or supranational entities trigger opportunities or threats at the firm level to develop NRIs, if they are combined with market and technology discontinuities.*

On the *micro* level which is defined here as firm and the embedded project context, obstructing and supporting factors in the major stages of the NRI process exist, too. In this context, there exists already extensive research on general success factors in NPD by scholars such as Cooper and Kleinschmidt (1993); Zirger and Madique (1990), or others. However, as pointed out above, the conceptionalization and measurement of the innovativeness and influence of specific discontinuities were not profoundly studied so far (Garcia and Calantone 2002; Daneels and Kleinschmidt 2001). Therefore, a more specific inquiry is needed as to which factors do apply at NRI. This aspect is added in the framework by the following proposition:

Proposition 2: *The obstructing and supporting factors in the firm context depend in a large part on the motivation and skills of firms to recognize and exploit the combined discontinuities as opportunities to develop NRIs.*

At the embedded project-level perspective, the main activities in the NRI process are taking place. The NRI process is divided into the concept stage – also called fuzzy front end (FFE) – and realization stage where NPD and market introduction proceed. Both stages are subject to different sets of obstructing factors (OF) and supporting factors (SF) as suggested by Veryzer (1998), Reid and Brentani (2004), Leifer et al. (2000), and Lynn et al. (1996). At the beginning, when the NRI opportunity (NRI-OP) which is based on firm-external combined discontinuities needs to be recognized by the firm and transformed into an NRI–FFE project, boundary-spanning and gate-keeper roles are required to cross the borders and combine creatively new trend trajectories. As research from RI processes suggest, this NRI-OP

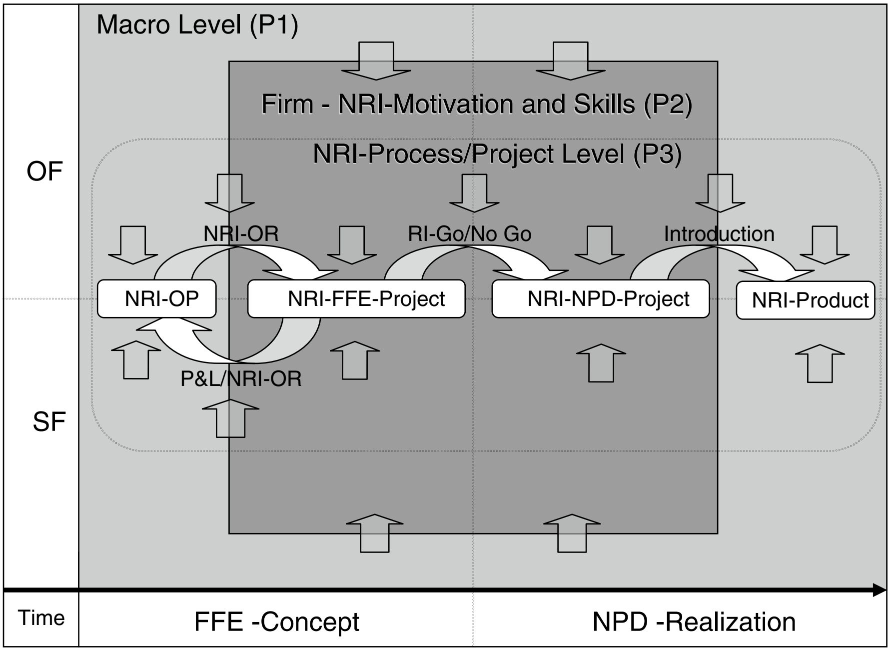

Fig. 9.3 NRI framework

leads to "probe-and-learn" (P&L) cycles where the new combinations are tested in quasi-market experiments with high failure rates due to the high uncertainty during the stages of the era of ferment at the macro-level (Lynn et al. 1996; Abernathy and Utterback 1978; Tushman and Anderson 1986). To cope with the external dynamics, the NRI–FFE on the firm level needs to be as flexible and experimental as the era of ferment at the macro-level. Therefore, more P&L cycles are typically needed in RI processes to finally identify a stable new product–market combination that leads to the new dominant design, opening the paradigmatic stage. If the NRI concept stabilizes, an NRI–NPD project and product can follow. Research from RI processes shows that these P&L cycles frequently need new recognition of the NRI-OP in the firm domain which often leads to the failure or disruption of the process since initial initiatives and supporters have lost their credibility in the organization (Leifer et al. 2000). This leads to the next proposition:

Proposition 3: *Facilitating repeated probe-and-learn and opportunity-recognition cycles is needed to successfully recognize and exploit the NRI opportunity at the firm level to develop NRIs.*

The overall preliminary theoretical framework for the NRI process is visualized in Fig. 9.3.

9.3 The Case of Mannesmann's Predevelopment Unit and the Project Robin for Germany's Electronic GPS-Based Truck Toll System

9.3.1 Case Selection, Methodology, and Data

The case of Mannesmann's predevelopment unit and the project ROBIN for Germany's electronic GPS-based truck toll system were selected to take a closer look at an innovation process where the specific national and supranational context played a decisive role in the development of a new product, service, and market combination that represented a novelty especially at the national level. Since road tolling is a typically locally based market with characteristics of infrastructure, it seems to be especially sensitive to the country context. This case describes and analyzes the rise of a late entrant in the area of electronic road tolling systems – Mannesmann AG – from a laggard nation without an initial regulation for road tolling since road infrastructure was traditionally financed by the government without costs for the users – Germany – in the traditional market of road tolling equipment which was before dominated by a number of established foreign incumbents with conventional technology. By faster anticipating and combining previously unrelated trends in the technological, institutional, and market domains, plus transforming them into a new radical approach by their predevelopment unit, the once lagging company managed to introduce the core of the new high-tech system for electronic road tolling in Germany – the so-called "on-board-unit." The case illustrates how a new entrant firm from a laggard national context had to face institutional resistance and political uncertainties due to its seemingly unfavorable national context conditions and managed to turn into a technological and national leader position.

Therefore, this case represents a unique case of NRI and justifies a single case study according to Yin (1994). To conduct the case study, a single case study with a multiple-level embedded design over a time period of 1992–1999 with an epilog in 2005 was chosen to investigate the theoretical framework described above in a real-life setting. To conduct the study, archival and interview data were used and analyzed. The researcher had exclusive access to internal archival data such as project documentation and reports on the project and firm level, which was complemented by publicly available documents and publications. Thirty-five thousand three hundred and forty two digital documents with a volume of 38,218 Mb have been scanned and analyzed alone. The document data were complemented by 11 in-depth interviews with key players at various levels of the process and organization with a total duration of 21 h. The interviews were conducted over a time period between March and August 2005 using a semi-standardized questionnaire. The interviews were taped, transcribed, and analyzed by using the hermeneutic, historical–critical method to apply triangulation to all types of data. The first step of the analysis included the reconstruction of a chronology of the events. After that, the framework was applied to the data and major stages were identified. However, the empirical data were not forced into the framework but the framework was used for an informed interpretation of the data as suggested by Yin (1994). Finally, the preliminary theoretical NRI framework was applied to the case and the propositions tested and the framework modified.

9.3.2 Mannesmann's Predevelopment Unit and the Project ROBIN[1]

9.3.2.1 Macrolevel (I): Discontinuities in the Early 1990s – Shaping of the NRI-OP

Electronic toll collection (ETC) systems appeared at first as applications of IFF (identification, friend or foe) technology in the civil sector in the beginning of the 1980s. The early concepts for ETC systems were based on simple tag systems, in which small electronic transponders – the so-called "tags" – are implemented in the vehicle which communicate via microwaves with a transmitter at the roadside to transfer the identification information. This information can be used to calculate the toll. Later, ETC systems were typically composed of four major components: automated vehicle identification, automated vehicle classification, transaction processing, and violation enforcement. In 1986, Norway has been the world's pioneer in the implementation of this technology in a real-life setting in Bergen operating together with traditional tollbooths. Other countries such as France, Italy, Spain, Japan, or the USA followed with similar ETC technologies.

The need for coordination of national private road operators in Italy, Spain, and France led to the formulation of common specifications of ETC systems. These coordination activities were complemented by EU research programs such as DRIVE[2] I and II to develop tag and chip card systems using microwave and infrared communication technologies. The goal was to harmonize the concept development in precompetitive R&D stage of the European ETC industry to be introduced into the European standardization process at the European Committee for Standardization. As part of this effort, the technical committee CEN/TC 278 "Road Transport and Traffic Telematics" was set up in July 1991, which was supposed to be responsible for developing the required system specifications for traffic telematics systems. Given the different starting positions in the European countries that had operated with partially manual toll collection, such as in Italy, which were more interested in the automation of existing infrastructure or had no road toll at all, such as Germany, and therefore was more interested in a fully automatic solution, there was a very heterogeneous regulatory requirement and technology situation with barely interoperable solutions. In this pre-paradigmatic situation of the early 1990s, the following multiple discontinuities occurred:

- New technological paradigms and possibilities, such as mobile positioning/GPS, digital, smart cards, telematics, and mobile data transmission (GSM, with initial data transmission capabilities).

[1] For more details and sources, refer to Hüsig (2006).
[2] DRIVE: Dedicated Road Infrastructure for Vehicle Safety in Europe.

- Creation of standards and standardization bodies for traffic telematics and ETC systems.
- Liberalization and privatization trends in infrastructure operation and construction.
- Increase in local and temporary shortages due to overloading of the traffic infrastructure, especially due to the German reunification and opening of East Europe.
- Increase in problems in the public financing of infrastructure.
- Increase in the resistance to extensions of the traffic area and by environmental needs.

9.3.2.2 Microlevel (I): Firm Context in the Early 1990s – Shaping of NRI Motivation and Skills

The context for the related innovation project on the firm level was the Mannesmann AG (MM), which was a German diversified capital goods corporation with significant commercial and service activities based in Düsseldorf, Germany. The company was founded in 1890 originally to produce seamless steel tubes which was a radical innovation developed by the founders. However, in the 1990s the MM AG had developed into a diversified technology company with operations in fields such as machinery, control technology, electronics, and automotive or mobile communication services. The firm's strategy focused traditionally on growth through businesses based on advanced technologies by internally building and externally acquiring new competencies which created significant growth, profits, and superior shareholder value over the long term. However, in the early 1990s, MM was investing heavily in the internal development of the new GSM-based mobile communication services and decided to sell most of its IT businesses to Digital Equipment. Nevertheless, the management realized the importance of IT-related know-how for the coming years and decided that it should not be completely lost through the sale of IT-related activities and companies. The importance of information technology for the remaining and future areas of MM was regarded as so central that the management required developing a solution that made it possible to maintain appropriate skills. As an organizational option, the creation of an innovation group was envisioned, which should specifically deal with IT-related topics that could possibly have relevance to the Mannesmann group. In one of the acquired high-tech start-ups of the MM group, a unique concept for such an innovation group was developed by the founder. He was also a professor at a technical university in Germany and developed the concept for a small, flexible, project-based predevelopment unit which was independent of the mainstream organization to monitor and pre-develop technological discontinuities which could lead to radical innovations. He based these ideas on the research of response strategies to the disruption of the German watch industry by digital technologies and own experiences with his innovations and start-ups. He was able to convince the CEO of MM to implement this concept as an internal start-up subsidiary called Mannesmann Pilotentwicklung GmbH (MPE) in 1991.

9.3.2.3 Microlevel (II): FFE of the NRI Process

Dynamic drifting/exploration stage[3]: Before the initial opportunity recognition, the multidisciplinary experts at the MPE explored and monitored various related technologies and EU programs such as EUREKA, ESPRIT,[4] or DRIVE in the fields of chip cards, identification, navigation, and sensors to analyze their relevance and potential for new and existing businesses of the MM group. Due to the business interests of MM in the areas of automotive and mobile communications, the MPE became interested in the new developments in the traffic telematics field and location technologies such as GPS.

NRI-OR (I): More detailed analysis of cost and performance trajectories of the GPS and related IT technology by the MPE revealed great application potentials in traffic telematics. Simultaneously, the MPE analyzed and forecasted the implications of the political and institutional discontinuities mentioned above that would lead to new solutions for traffic infrastructure such as road tolling. These trends were combined into an idea for a new ETC system based on GPS and mobile communications which would open up a potential new business area for MM.

NRI–FFE project formation and formative prototype development: This idea was further developed to a concept that was supposed to be an alternative to traditional ETC systems. The intended advantage of an ETC system based on GPS was primarily seen in the total substitution of the investment-intensive roadside infrastructure through GPS positioning and GSM mobile communication technology. Traffic flow and streetscape should remain completely unaffected by the road tolling process. The concept envisioned to identify the toll road, calculate, and collect the toll exclusively in the vehicle by an on-board unit (OBU). A call for applications in 1993 to participate in a German field trial to test ETC systems for a German truck toll by a German government institution represented the trigger event to launch a project called ROBIN (Road Billing Network) in order to test and pre-develop these ideas and concepts by the means of a formative prototype for this field trial. The approach of the MPE consisted in improving the accuracy and reliability of GPS technology by new algorithms embedded in software and proving the feasibility of that approach by means of a prototype. Supported by external experts and extra budget by the senior management, an initial prototype and patents were developed.

P&L cycle (I) and transfer to realization: The MPE successfully managed to qualify for the participation in the field test of the Federal Government in a relatively short time. Out of 126 expressions of interest received in May 1993, only ten applications for field test remained in the summer of 1993 after a preliminary investigation by the testing agency, which was assigned by the government, among whom also the

[3] Veryzer (1998) called this type of activity *dynamic drifting* in the early stage of RI processes which fits in here as well.

[4] ESPRIT: European Strategic Program on Research in Information Technology.

ROBIN system of the MPE was chosen. Through the new MPE unit, MM managed to catch up from a laggard position within a few months to achieve what the established industry heavyweights such as Marconi, Autostrade, Texas Instruments, or Alcatel SEL had developed within 3–4 years in the area of ETC systems. This success also opened up the so-far closed clubs of standard setting bodies where the incumbents discussed the future of ETC systems. Additionally, the MPE managed to create an MM-group-wide taskforce to develop a comprehensive strategy to exploit the opportunities related to traffic telematics in new organizational structures. Most members of the NRI–FFE project team were transferred to the new units and started to develop services and systems in the traffic telematics area. However, these units dealt primarily with the development of traffic telematics services, since the road toll regulation needed for ETC systems still seemed relatively far away due to political uncertainties.

9.3.2.4 Macrolevel (II): Institutional Discontinuities and New Entrants in the Mid 1990s

The directive 93/89 EEC emerged in October 1993 and defined between Germany and other European countries the implementation of the convention on a road toll for trucks by using a vignette system, which creates the regulatory requirements for road toll charging in Germany. This new regulation was implemented in German law in 1995 and finally created a novel market for ETC systems in Germany. In 1994, another firm consortium introduced an ETC system based on GSM technology: Deutsche Telekom together with the French Sagem. However, in July 1995, the European Court repealed the relevant directive 93/89 due to procedural errors. Nevertheless, the German Transport Ministers decided in November 1995 to introduce a distance-based truck toll on German motorways with automatic tolling in the year 2000. In the summer of 1996, the EU Commission had presented a proposal for a directive (KOM (96) 331 final of 10 July 1996) to the Council of Europe, which included the future basis for the levying of user charges (time related) or toll (distance related) by the EU member states. This directive entered into force on 1 Jan 1998 and should remain effective for at least 3 years.

9.3.2.5 Microlevel (III): New P&L Cycles in the NRI Process During the Era of Ferment

P&L cycle (II): Between May 94 and June 1995, a field trial of the federal ministry of transport for the test of automatic fee collection techniques was performed. In addition to various conventional approaches, also the MPE and Deutsche Telekom/Sagem took part with their new GPS/GSM-based systems in the field trial. The evaluations of the field trial showed that a general road toll was not yet possible, but a truck-toll system appeared feasible with the audited ETC systems. Moreover, the evaluations also revealed that the industry was still in an early development in multilane-capable ETC systems and although the GPS-based systems possessed no fundamental advantage over the infrared systems, it were the two GPS-based systems in the top three test results, while the majority of the other participants had hardly managed to even come close to fulfilling the potential user set criteria. These poor results for the major established competition were dramatic, particularly in consideration of their multiple higher investments compared to MM with their MPE approach. In particular, the control of the toll collection process did not work as the potential users wanted, so that the competition between the different system technologies should continue to remain open and was promoted only by the definition of framework specifications. Thus, by the Ministry of Economy and SME, a second field test was carried out in which the criticized control capabilities of the ETC systems should be tested. In this field test, advanced control bridges were tested, which should distinguish between toll payers and toll cheaters. This type of toll enforcement and control was not according to the ROBIN concept without additional roadside infrastructure, which would increase the investment costs dramatically.

P&L cycle (III): In the beginning of 1997, the MPE autonomously started another initiative to develop the truck toll project in collaboration with the other MM units to address the new requirements of the emerging NRI-OP for the truck toll operation and systems by a new system approach plus building up a consortium together with some former competitors. However, the consortium could not agree on a common strategy, split up, and the initiative was ended.

9.3.2.6 Macrolevel (III): Institutional Discontinuities and Competing ETC Standards

In April 1998, the open call for tenders for the toll processing services appeared in the EU official gazette. In addition, in early August the EU project INITIATIVE[5] was initiated, which targeted to support the shaping of a framework for a pan-European standard for ETC systems. At this time, three different ETC system technologies competed for the future industry standard: OCR (optical character recognition), DSRC (dedicated short-range communication), and the GPS/GSM/DSRC systems in which the MPE has become the technology leader. Originally, the distance-related truck toll should have been introduced in 2000 in Germany, but after the new schedule of the Federal Ministry of Transport, this date was postponed by 1 year. Accordingly, the tender for the toll operation was moved from summer 1999 to early 2000.

[5] INITIATIVE: Industry initiative to introduce automatic tolling in vehicles in Europe.

9.3.2.7 Microlevel (IV): New NRI-OR, Final P&L-Cycle, and Transfer to NPD

Against the background of the initially released call for tenders for construction and operation of the German toll system, the truck toll project by the MPE in cooperation with the other MM units was started again. Two parallel projects were started to address the technological and organizational challenges. Although the specific user requirements and traffic telematic service applications were still unclear, the MPE started to develop another prototype for the OBU. To address these problems, three different OBU concepts with similar architecture were developed simultaneously. Finally, the product development of the OBU was transferred to the operative units of MM such as VDO. Furthermore, in the summer 1999 of a consortium for construction and operation of the German truck toll, under the name of AGES, was finally established by MM and other partners.

9.3.2.8 Epilog: NRI Introduction and Impact

In early 2000, the award procedure as competition for the toll operation was launched. After the expiry of the submission deadline, six providers had submitted an application for participation. Of these, five were invited, to make an offer until 31 Jan 2001. Only three suppliers submitted in a timely manner – among them was the AGES consortium with MM as a consortium partner. In May and August 2001, the Department of Transportation excluded a competitor and the AGES consortium from the process because of their insufficient financial resources. This meant the contract went to ETC.de, which later became Toll Collect. Against this decision, AGES filed a suit until the court of ultimate resort noted on 21 Dec 2001 that the Department of Transportation wrongly excluded the AGES consortium from the tendering procedure, and the procedure had to be reset. The planned start of the truck toll on 1 Jan 2003 was no longer possible to keep.

In the summer of 2002, ETC.de/Toll Collect GmbH again received the acceptance of bid, since it calculated the cost of the OBUs and toll terminal lower than AGES and also promised a 3-month earlier delivery. AGES complained to the Federal Cartel Office, as the consortium questioned that the competitive system would at all meet the minimum requirement of fee collection and control. In the course of further legal argument, the two competitors finally agreed out of court, so that Vodafone could get in place of MM in AGES consortium a substantial interest in the operation of the toll communication data revenue.[6] After these delays, Toll Collect was supposed to start the system's operation in August 2003. However, because of serious technical problems Toll Collect could not meet this date and the contracts, which led to another postponement of the start date.

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[6] MM was taken over by Vodafone in 2000.

In February 2004, the Federal Government and the shareholders of Toll Collect agreed to introduce the truck toll system with limited functionality on 1 Jan 2005. However, now Siemens VDO got the responsibility for the technical coordination of the project to supply a 100% working OBU. VDO had been part of the former MM Group which was sold by Vodafone to Siemens. VDO's OBU was using the technology developed by MPE before. Just after 2 months, Toll Collect published on their technical progress and improved performance and reliability of the new ETC system and the market introduction could start with the VDO OBU. By August 2005 about 450,000 OBUs have been implemented into German and foreign trucks. Siemens VDO manufactured about two-thirds of the equipment. With an estimated cost of 1,500 € per OBU a turnover of 450 € million was already achieved after a few months after the introduction. A follow-up version of the OBU was in effect with the full functionality in 2006.

9.4 Theoretical Implications and Propositions for Future Research

9.4.1 The Total Project-Radicalness Matrix Applied to the ROBIN Project

Before analyzing the case study using the NRI framework, the innovation process has to be evaluated in terms of innovativeness. Therefore, the new approach and categorization scheme developed above was used to analyze the ROBIN project and outcome. The total project-radicalness matrix helps to clarify if this case can be categorized as NRI which is analog to the RI context subtype of *nation-level radical*. The concept of NRI is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, and achieved by an innovation project in the context of the nation.

In the *concept* phase, a major system innovation was planned which would combine communication technologies and apply them to the traffic area, where they had not been used up to this point. Technologies, application fields, industry, and market factors were unfamiliar at the *firm level*. Although there was little necessity to substitute existing technological and market capabilities, the need for change at the resource base of Mannesmann was high. According to the categorization scheme, it represented a *radical concept* and was *firm-level radical* at this stage. Although the traditional industries themselves (systems for electronic road pricing, navigation and traffic management) already existed, the concepts developed regarding technologies and applications were unfamiliar for the incumbents. Therefore, the project was also *industry-level radical* at this stage. The same was true for the *national level* (Germany), where road pricing hardly existed at all as a market since the public infrastructure was toll-free (*nation-level radical*). On a global scale, the same degree of innovativeness was achieved at this stage (*global radical*). Over all context levels, the ROBIN project represented a *radical concept* according to the categorization scheme.

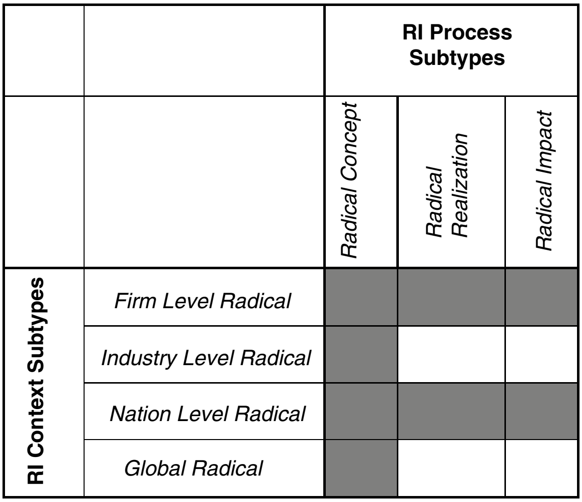

Fig. 9.4 Categorization of the ROBIN project in the Total Project Radicalness Matrix

Also, in the *realization* phase, the project stayed *firm-level radical*, although Mannesmann was taken over by Vodafone, the project was continued by the successors. At the industry and global levels, some modifications to the original concept led to a reduced degree of innovativeness, since many of the new applications were not realized due to external reasons (competitor won part of the market, core component instead of operator and system business, and legal/political problems). However, in Germany institutional changes laid the foundations for the establishment of this new market, so that the project was also *nation-level radical* in the realization phase.

The impact of the ROBIN project is again context- and time-specific: After the successful introduction of the so-called "Toll Collect System" at the beginning of 2005, the requirements for technological and market successes simultaneously achieved by the innovation project were fulfilled. A new core product called "on-board-unit" was mass produced (over 500,000 units in April 2006) and sold to a new customer (system operator), with estimated revenues for the successor unit VDO of 450 € million, controlling three-quarters of a new market (road pricing equipment) which had not previously existed in Germany. This indicates a *nation-level radical* categorization, since there has not been a successful market entry in other countries, and the firm has only an unclear product advantage over competing systems for electronic road pricing which have been developed elsewhere in the meantime. Therefore, this innovation can be categorized as NRI. Figure 9.4 summarizes these results.

9.4.2 Application and Modification of the NRI Framework

Based on the preliminary theoretical framework for the NRI process and the related context levels, the case study is evaluated and modifications for the framework are proposed as suggested by Yin (1994). The case study showed that the framework needs to be expanded to include a number of aspects which were missing in the theory so far but also confirmed some of the propositions.

The proposition regarding the *macro-level* has been supported by the case study. Multiple, simultaneous discontinuities in markets, technologies, institutions, and regulations provided an environment of high uncertainty, in which new entrants are able to shape new combinations in from of NRI. However, the ROBIN case also indicated that institutional and regulatory discontinuities originating from national or supranational entities themselves are also triggered by changes in the market and technological domains. New possibilities in technology or market demands enable or limit the need and reach of regulatory change. Various government bodies on different levels and originating from different countries in supranational context amplify the institutional uncertainty as they try to address different local demands. This heterogeneity enables novel solutions in pre-paradigmatic stages of industries such as emerging the ETC systems industry which was originally shaped by the local conditions and path dependencies. As long as local demand conditions remain heterogeneous, institutions and technological discontinuities provide opportunities for NRI. Proposition 1 is modified accordingly:

Proposition 1: *Institutional or regulatory discontinuities originating from national or supranational entities trigger opportunities or threats on the firm level to develop NRIs, if they are combined with markets and technology discontinuities and as long as local demand conditions remain heterogeneous.*

As a supporting factor in the *firm context* appeared the motivation and skills in diversification capabilities as observed in the MM case for the NRI process. willingness for and experience in diversification provided sufficient resources and a long-term orientation toward exploring and exploiting NRI opportunities. This aspect modifies Proposition 2:

Proposition 2: *The willingness for and experience in diversification on the firm level provides sufficient resources and a long-term orientation toward exploring and exploiting the combined discontinuities as opportunities to develop NRIs.*

At first glance, the original proposition at the *microlevel* of the NRI process was supported by the innovation process of the ROBIN project. Multiple probe-and-learn and opportunity-recognition cycles were needed to cope with the multidimensional uncertainties. Therefore, Proposition 3 is supported by the case evidence:

Proposition 3: *Facilitating repeated probe-and-learn and opportunity-recognition-cycles is needed to successfully recognize and exploit the NRI opportunity at the firm level to develop NRIs.*

However, particularly the FFE of the NRI process indicated that these activities could be supported and initiated by *specific organizational approaches* such as the MPE in the case of MM, which seems to enhance the NRI skills of large firms in terms of dynamic drifting, NRI-OP, NRI-OR, and P&L cycles. The existence and

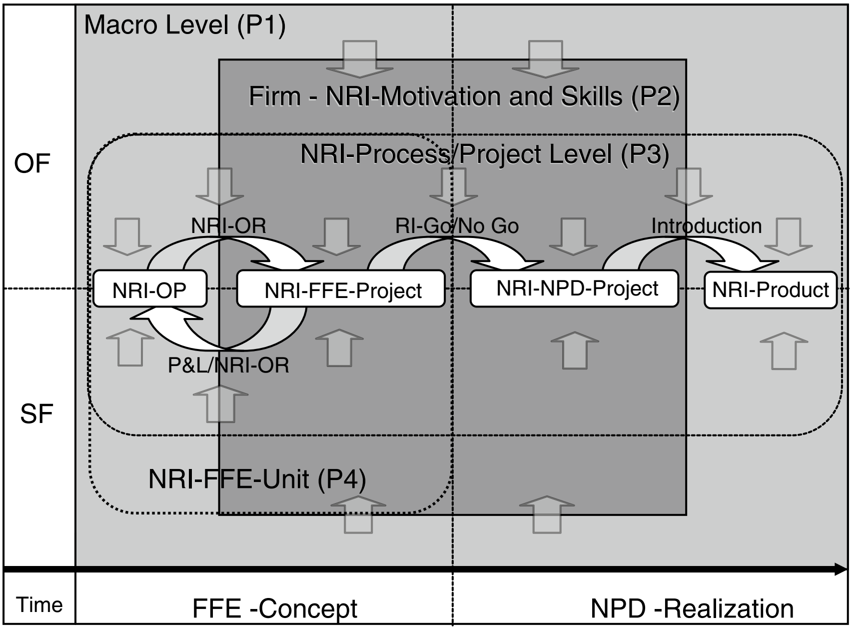

Fig. 9.5 The modified NRI framework

characteristics of specific organizational approaches for the FFE of RI processes seemed to be a success factor by providing the necessary environment and resources into this long-term, uncertain process. The MPE helped to shorten what Veryzer (1998) called dynamic drifting in the early stage of RI processes by means of small, multidisciplinary people and teams with the support of external experts, which fit in here as well. The institutionalization of exploration function originally planned for technology discontinuities was expanded to other environmental changes, which enabled further combination capabilities fostered by multidisciplinary people and teams. This role of institutionalization of the NRI–FFE needs to be further explored. The theoretical framework needs to address this aspect by adding another context level and the following Proposition 4:

Proposition 4: *Specific institutionalization of the FFE activities of NRI projects enhances the NRI skills of large established firms in terms of dynamic drifting, NRI-OP, NRI-OR, and P&L cycles by providing the necessary environment and resources.*

Building on the new insights from the case analysis, the preliminary NRI framework can be modified by introducing the new propositions into the original concept. Figure 9.5 shows the modified NRI framework.

9.5 Conclusions and Future Research

This chapter addressed multiple research questions, such as how radical innovation at the national level can be conceptualized, or which role the national and supranational institutional factors play in these radical innovation processes at the national level and what success factors at the firm and project level exist for them. Finally, it targeted to explore how these kinds of innovation projects or processes take shape.

The analyzed case of the ROBIN project illustrates how the proposed innovativeness framework and the corresponding categorization scheme, the total project-radicalness matrix, can be applied and how the concept of NRI could be defined. So far, there is no framework which integrates these multiple perspectives on innovativeness and radical innovation holistically. The total project-radicalness matrix presents new RI project subtypes and improves the overview of possible characteristics of innovation projects. The matrix enables a more finely grained categorization of innovation projects and allows for a distinction of the degree of radicalness depending on the context and stage of the innovation process. This step-by-step and context-dependent categorization enables researchers and managers to evaluate the innovativeness of an innovation project dynamically over the major stages of the innovation life cycle. By using the above framework it was shown that the differences in their degrees of innovativeness could be rendered more explicit, thereby improving our understanding of the radical innovation phenomena. Using this framework, NRI is understood as a specific type of RI which is analog to the RI context subtype of *nation-level radical*. NRI is defined as a new combination of technological and market discontinuities simultaneously aimed at, implemented, and achieved by an innovation project in the context of the nation. Last but not least, this framework might also help practitioners who are in need of better innovation categories for improved communication, evaluation, and management of single projects or project portfolios. In this chapter, this gap in the literature is addressed and an attempt is made to improve the measurement and categorization of radical innovation projects regarding the influence of institutional factors and the national context.

Although the national context is often perceived as losing relevance due to increasing globalization and integration of regions and the world economy, this chapter described and analyzed an innovation process where the specific national and supranational context played a decisive role in the development of a new product, service, and market combination that represented a novelty especially at the national level: A new high-tech system for electronic road tolling in Germany. The rise of Mannesmann AG, a late entrant in the area of electronic road tolling systems from a laggard nation without an initial regulation for road tolling like Germany, showed that by more quickly anticipating and combining previously unrelated trends in the technological, institutional, and market domains, plus transforming them into a new radical approach by their predevelopment unit, the once lagging company managed to introduce the core of the new high-tech system for electronic road tolling in Germany – the so-called "on-board-unit." The case illustrates how a new entrant firm from a laggard national context had to face institutional resistance and political uncertainties due to its seemingly unfavorable national context conditions and managed to turn into a technological and national leader position. Therefore, this case represents an extreme case of a specific type of NRI where novel technologies are combined to address a new application in an emerging market at the level of the national context.

The NRI framework provided new theoretical insights into this process and multiple propositions for future research were developed. Especially the use of specific institutionalizations for the FFE activities of NRI projects which seem to enhance the NRI skills of large established firms in terms of dynamic drifting, NRI-OP, NRI-OR, and P&L cycles by providing the necessary environment and resources should be researched in more debt. More NRI processes should be researched to enhance the preliminarily insights here and compare them with experiences from other institutional or industry contexts since countries often have unique institutional features in relation to other countries; therefore, it is quite possible that factors associated with effective managerial responses to NRI in one country may not apply in other contexts (Chesbrough 2003). However, as the study has shown, even if supranational entities triggers institutional harmonization through standard-setting bodies, these regulatory discontinuities can provoke opportunities at the firm level to develop NRIs, if they are combined with markets and technology discontinuities and as long as local demand conditions remain heterogeneous. Further research should also explore if the willingness for and experience in diversification at the firm level provide sufficient resources and a long-term orientation toward exploring and exploiting the combined discontinuities as opportunities to develop NRIs under the various local demand conditions. Finally, an unexplored question remains – which kind of policy implications should NRI have at the supranational context for future institutional change?

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Chapter 10
Japanese Firms' Innovation Strategies in the Twenty-First Century: An Institutional View

Robert Eberhart and Glenn Hoetker

10.1 Introduction

The landscape within which Japanese companies innovate stands altered by events of the past two decades. Buffeted and metamorphosed by the forces of a severe asset value decline beginning in 1990, and a decade of economic malaise, followed by a subsequent decade of growth – and now the recent financial crisis – Japanese firms are transforming their innovation strategies because the national institutional framework of those strategies is altered by new economic realities. Even though the basis of the strategies that evolve from the framework, and perhaps the strategies themselves, are changing, Japan is more than maintaining its level of innovation, according to recent data. Even small companies seem to be increasingly part of recent innovation outcomes. So we ask, how is the level maintained given that the strategies that created Japan's acknowledged industrial innovativeness seem to be transformed by events?

The institutional framework of the innovation strategies that Japanese firms created and used to great advantage in the 1980s was transformed in the post-asset-bubble period of reform in Japan. We find that, while the strategies of innovation have changed because of institutional and economic alterations, Japanese firms are, on aggregate, maintaining a substantial level of innovation by using the human and economic legacies of the older equilibrium that remains complementary to new realities. Moreover, Japanese firms seem to be adapting by taking advantage of the global supply chain to focus industrial effort and fostering new enterprises in Japan

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with an increased emphasis on product innovation, particularly in communication, Internet, renewable energy, and machinery industries. Thus, there is both a momentum effect and a shift to product innovation.

Specifically, we suggest that the institutional structure of the past created a reliance on human capital (because of stable employment and the economic imperative to train employees for whom termination was not the norm) and that the collectively intentional creation of effective human capital persists through and after institutional reform as a testament to its efficacy and path dependency. We will show that Japanese firms tend to find the human capital development tactics of the past complement the new realities. Thus, the companies maintain an empirical momentum in innovation while a new equilibrium is forming.

The innovation strategies of Japanese firms during the pre-bubble decade were predicated on three institutional supports: long-term business relationships, a main bank supervised corporate governance system, and labor market stability via lifetime employment. Subsequently, after a series of legislative reforms and a period of bank instability, these institutional bases became obsolete, and firms sought new strategies for profit maximization. New economic strategies made it more imperative for firms to focus on the most profitable lines of business in the most value-added phases of the value chain.

One consequence of this new focus was the continuing move of manufacturing to offshore, implying further alteration of strategies for Japan's companies. We suggest that Japanese firms have responded by product innovations in new industries that rely on the strength of human capital development strategies that worked well in the older equilibrium. Further, a combination of government policies aimed at empowering the market and fostering new company formation and the desire to emulate the rapidly rising equity values in the US NASDAQ market have resulted in new firms that, of their nature, create business process and product innovations. This is not to say that a new equilibrium of optimal innovation strategies is already established. Rather, we argue that the combination of efforts to alleviate economic difficulty, along with a path-dependent habit of fostering human capital, enables Japanese firms to continue innovative strategies.

This chapter will examine

1. The equilibrium that characterized Japanese industrial organization and thus innovation strategies until the financial problems of the 1990s,
2. The transformation of the institutional framework within which innovation took place as Japanese industry reforms were implemented and the shared knowledge and organizational habits of the past became obsolete.
3. How strategies established in the earlier equilibrium, as behavioral and organizational outcomes, find complementary usefulness in the context of new industrial architectures that may explain at least partly why Japanese firms maintain a substantial level of innovation.

10.2 The National Institutional Framework Perspective

The term "national innovation system" or "Japan's innovation system" is a sometimes a misleading term. Japan is not an economic agent of interest with respect to the subject of innovation. Although this is well recognized in the extant innovation literature, we adopt a different vernacular, that of the institutional innovation framework, to make explicit that we are not deliberating policy at the national level. Rather, we are analyzing the response of firms to changes in the legal, economic, and informal institutional framework.

While much insightful literature on innovation, whether focused on Japan or other countries, is approached from the viewpoint of strategy within the firm, and conditioned by resources, organizational structure, or the competitive environment confronting a particular company (Chesbrough 1999; Chandler et al. 2001), our focus is on the varied institutional phenomena, common business beliefs, behavioral regularity, and collective intentionality that comprise innovation as a strategic outcome.

So, this chapter will focus on the economic environment of Japan within which firms maximize their objectives by choosing, among a multiplicity of potential business strategies, to innovate. Our viewpoint is that innovation is undertaken by firms to gain a competitive advantage in its marketplace within the analytic paradigm of comparative institutional analysis (Aoki 2001). Thus, the selection of an innovation strategy of a firm is conditioned by the institutional framework of business habit, traditions, path dependencies, and legal constraints. In other words, innovation is a strategy for success in a marketplace, and the particular innovation strategy selected is an outcome conditioned by institutions that both catalyze and constrain profit maximization.

10.3 The Stratagems of the Past

The rapid recovery of Japan's economic systems and markets in the postwar period is well and thoroughly documented. Since the oil supply crisis of the early seventies until 1990, an equilibrium of Japanese business strategies developed within the national institutional framework that was both stable and innovative. It was what Imai calls "a system of rigid flexibility" (Imai 2007). While product innovation was important in this period (e.g., Sony and fuel-efficient cars), process innovation as a source of rising productivity was also important (Kenney and Florida 1988).

This stable equilibrium developed as a firm-level institutional response to an informal discussion in the business community in Japan as to what were the best strategies for firms facing increasing input costs and more open global markets and how to handle redundant employees as circumstances changed (Yoshimori 2005). In the case of redundant employees, the institutional labor market norms in Japan eschewed layoffs, yet inefficiencies would naturally arise should redundant employees be retained. Facing the additional pressures of rising energy costs in the 1970s as well as price competition for other industrial inputs, Japanese firms were constrained to adopt what became a famed system for improving industrial productivity.

Kanban inventory management systems, work teams, and total quality management are just a few examples, (Schonberger 1982). Input factors, labor, capital, and raw inputs, were thoroughly, and in a continuous manner, reengineered to obtain maximum productivity and lowest costs consistent with market demands for increasing market quality (Nagaoka and Flamm 2006).

A quasi-national system emerged from these economic pressures. We use the word "quasi-national" as it was not a designed system – bureaucratically or legislatively. It emerged as a system of common beliefs and shared behaviors in response to those beliefs, perhaps best collectively called, after Aoki, the J-Firm, or by others the "Japanese Model." As a succinct summary of this model, Motohashi (2003) wrote:

> The term "Japanese model" is a comprehensive reference to a unique management style that has been practiced by Japanese corporations as Japan's economy developed in the postwar period. With regard to business practices, it refers to the maintenance of long-term business relationships; with regard to human resources management, it refers to lifetime employment and reliance on seniority; in the financial sphere, it refers to a heavy reliance on indirect finance; and in corporate governance, it refers to the preponderant influence exercised by main banks.

Using Motohashi's framework, there are three key pillars of the Japanese model from an institutional viewpoint:

1. Long-term business relationships.
2. Main Bank Governance System for corporate stability.
3. Labor market stability via lifetime employment.

During the 1980s, currents of scholarship led to two complementary streams of reasoning to explain Japan's innovation architecture: the influence of favorable government policies and a unique equilibrium of Japanese corporate management techniques. The unique structure of Japan's innovation was presumed to be the confluence of efforts where governmental guidance and financial support on selected areas of innovation were complemented by innovative manufacturing and management processes, as well as advantageous information-sharing processes, and the idea of the "knowledge creating company" described by Takeuchi, Nonaka, and others (Nonaka and Takeuchi 1995). On a more analytical level, Masahiko Aoki developed a theoretical model of Japanese management noticing the institutional complementarity between organizational architectures such as between long-term employment relations and the main bank contingent governance system (Aoki 2001). In particular, the main bank intervenes only in the event of financial trouble, letting management to pursue longer-term strategies than possible under the US system of the market for corporate control. From a game-theoretic point of view, institutional complementarities, such as this, mesh as stable and repeated strategies. Importantly for the new equilibrium now emerging, a change to any single institution implies a realignment of the entire system.

10.4 Changes in the Basis of Innovation Strategies

The equilibrium of the Japan model was shattered in 1990 as the collapse of the Japan asset bubble was expressed in a two-thirds decline in the Nikkei 250 stock. Unemployment climbed to a postwar record level of 6.1%, the business bankruptcy rate climbed to a record rate of 10%, and property values, in the Tokyo metropolitan area, fell by more than 70%. Three of Japan's five major banks became illiquid and on the verge of bankruptcy (Fig. 10.1).

It is unlikely that the status quo could be maintained in Japanese companies after 1990. The persistent decline in Japanese asset values during the 1990s engendered much policy, legal, and corporate strategic responses. As the Japanese economy reached its nadir after the collapse of its asset bubble in 1990, the economic developments affected innovation strategies of many Japanese firms, and assessments of Japan's innovation structures increasingly became the subject of reexamination. Once vaunted as the engine of the "economic miracle" of Japan's postwar growth, a broad business and policy criticism arose during the prolonged post-bubble recession, and blossomed during the subsequent recovery, that the innovative architecture of Japan was no longer relevant to a new economic logic in a globalized setting with important rising Asian competitor countries (Fig. 10.2).

We propose that the three pillars of Japan institutional innovation strategies, critical to the sustenance of the Japan Model, have been challenged because their underlying economic forces have been altered:

1. Main bank finance and contingent governance is transformed by the reorganization of the banks.
2. Lifetime employment is transformed by the abandonment of this strategy by firms and the use of temporary workers. This changes the organizational architecture and shop-floor cohesion affecting the information transfer crucial to the model of the J-Firm.
3. Fundamental change in business location forcing new business relationships and transforming business strategies.

10.4.1 Main Bank Finance and Contingent Governance Changes

A broad criticism arose of Japan's system of contingent corporate governance and associated monitoring system during the 1980s. Partially in response to this criticism and the general desire for reform after the bubble, a series of legal changes to the corporate laws was enacted, three of which this paper takes note of. First, the new laws provided for increased efficacy of and propensity for minor shareholder activity. Second, legal barriers against merger and acquisition activities were further eased. Third, corporate governance systems were made more transparent making financing from nonmain bank sources more tenable (Nottage et al. 2001).

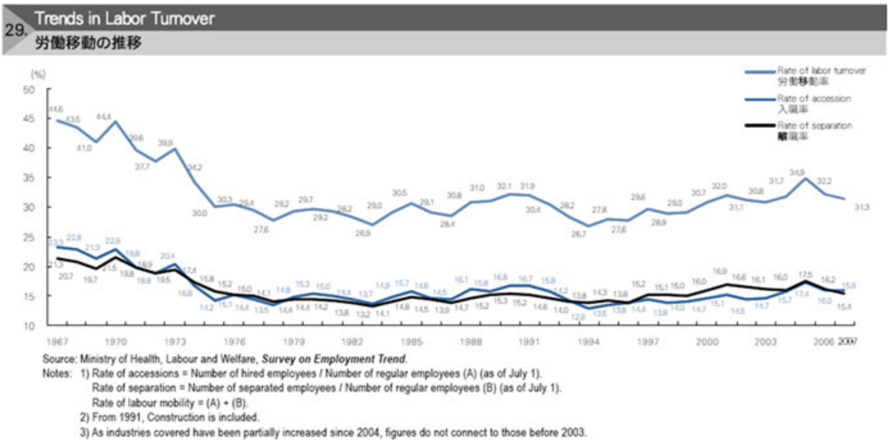

Fig. 10.1 Researchers in the labor force

Fig. 10.2 Trends in production of innovative knowledge

The main banks also had their own problems. The main bank system discouraged effective monitoring when playing the role of first lender by reviewing and monitoring a company's investment projects and coordinating with other banks to supply funds. Since the bank had direct access to their customers' accounting information – and access to almost all other inside company information – and since the bank provided the critical contingent governance, there was little incentive to inform other stakeholders, (Gordon 1999). Further, since new alternate sources of finance became available in Japan during the 1980s and 1990s (apart from main bank finance), the contingent governance system did not provide adequate transparency for the new sources of capital (Maswood and Miyajima 2002).

Moreover, the main banks were short of capital in the post-bubble period, and they were obliged, under the old system, to maintain a flow of funds to so-called "zombie" firms (Hoshi and Kashyap 1999). The banks, by maintaining lending in an illiquid environment, found themselves bankrupt and eventually reorganized. Illiquid banks undergoing reorganization are not in a position to exercise the contingent governance crucial to the operation of the Japan Model. The Japanese government during the 1990s implemented a series of counter measures to shore up the banking system. These included a loan-purchasing program set up in 1993, followed by the establishment of banks to buy out failed credit cooperatives and the *Jusen* that culminated in the reorganization of the supervision authority for banks. Further, the Ministry of Finance established an ¥60 trillion fund for bank recapitalization. In 1998, the Long-Term Credit Bank (LTCB) of Japan and Nippon Credit Bank (NCB) were nationalized and reorganized, and three regional banks were put under receivership in the first half of 1999. In March 1999, 15 large banks applied for a capital injection and received ¥7.4592 trillion of public funds (Hoshi and Kashyap 1999).

A consequence of all this was a disturbance to the equilibrium of governance relationships and an unwinding of their structures; cross-shareholding declined; and the keiretsu lessened in importance.

Additional reforms were promulgated to encourage new forms of financial intermediation. Tax benefits created for "angel" investors, foreign venture capitalists foreign private equity, and foreign lawyers became common. Purchase of shares with shares, triangular mergers, and repurchase of shares were all allowed. Moreover, several new stock exchanges were created expressly for relatively new companies (Vogel 2006).

Corporate governance laws were also revised. For one, Japanese firms may now use US-style board of director committees, with an upper limit placed on directors' liabilities. Japanese auditors are now required to be outsiders, and consolidated accounting is likewise compulsory, as well as "mark-to-market" rules for financial reporting. These are just a few of the changes, all of which combine to increase transparency in Japan's economic framework (Eberhart 2009).

10.4.2 Labor Force Changes

Shop-floor process innovation of the Japan model depends on, among other things, the labor management, and training system within and without a firm. That system was structurally changed in the post-bubble period as more and more firms reduced dependence on lifetime employment systems and adopted the technique of hiring temporary workers. These workers could be terminated at will, were paid generally less, and had less benefits (Schaede 2008). More importantly, the mechanisms of shop-floor decision making and tactic knowledge are untenable in a high labor force turnover situation. As recent events have shown, high turnover is manifest in

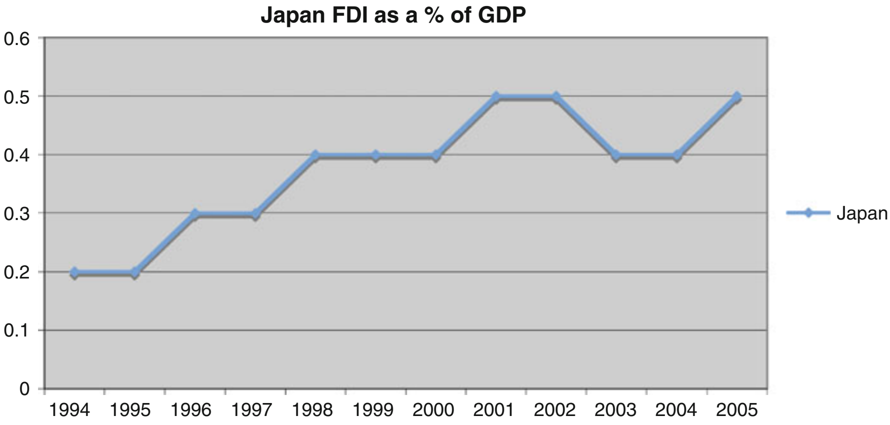

Fig. 10.3 Trends in production of innovative knowledge, including Japan

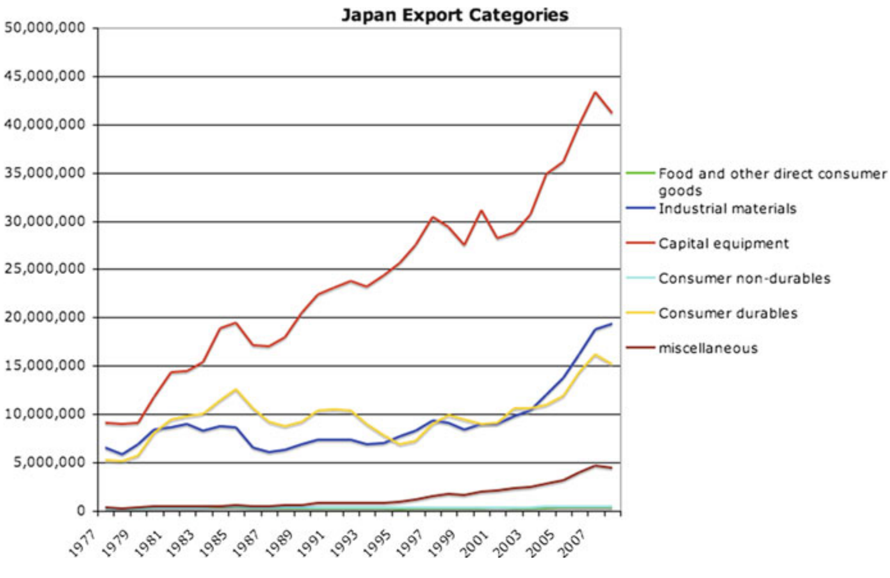

Fig. 10.4 Patenting in key technical fields

21st century Japan. The rate of labor mobility ((hired employees + separated employees)/regular employees) in Japan has increased since its lows of 26–30% annually in the 1980s to between 31 and 35% since 2001, and the type of jobs being held are transforming as indicated by union membership, which has fallen steadily since 1980 from 30.8 to 18.1% in 2007 (J.I.L.P.T 2008) (Figs 10.3 and 10.4).

10.4.3 Externalization of Manufacturing as a Strategy

In her book "Choose and Focus" Schaede (2008) gives an account of the dynamic forces that shaped new strategies for Japanese firms and the new quasi-equilibrium strategy of choose and focus that arose late in the 1990s. In the Schaede analysis, Japanese firms engaged in a massive restructuring. Since 2003, after legal reforms were largely enacted, fully 75% of Japan's 475 largest companies restructured via divestiture, merger, or corporate reorganization. Alternatively, to look at it with another perspective, only 25% of Japan's largest firms engaged in no restructuring at all. How remarkable this is, as Schaede points out, is that compared to a period of major US firm restructuring, in the 1980s, the percentage of US companies that engaged in similar activities was only 20%. Japan's corporate restructuring must be seen as a major strategic inflection point.

There has been a widespread rise in the proportion of Japanese manufacturing that occurs offshore. Soon after the collapse of the asset bubble, as firms sought lower costs of production, the proportion of overseas production more than doubled from 1993 through 1996 (Cowling and Tomlinson 2003). Concurrently, economic forces were unleashed that were to transform business imperatives from a more market structure level. Reforms in China and subsequent reforms in Southeast Asia made access to comparatively inexpensive labor and factor markets possible (Vogel 2006); not only possible, the tactic was indispensable too.

Japan's FDI into China and Southeast Asia reached record levels, and the identified trend is for Japan to export components and machinery to owned plants in other countries (Aminian et al. 2007). While final assembly occurs overseas, profits accrue in Japan, but the supplier–buyer relationships are disrupted. Recently, the trend has been made most manifest in Japan's trade data as exported capital goods, to supply new offshore factories, has grown faster than any other export category and come to be the majority of Japan's exports with profound consequences for the macroeconomy.

There is evidence that manufacturing process innovations, developed and implemented in Japan, do not transfer effectively to Chinese or other countries' facilities. Taylor, in a survey of manufacturing and management practices in China, located subsidiaries of Japanese firms, found that manufacturing and managerial methods do not necessarily transfer, and that Japanese firms cede much of the local management by necessity (Taylor 1999). There is also an observed effect on Japan's domestic manufacturing skills as a study of more than 1,000 Japanese firms with offshore manufacturing operation found a reduction in shop-floor knowledge intensity in those firms as foreign operations increased (Head and Ries 2002).

It is worth noting, however, that product innovation, which encapsulates process innovations in complete, modular pieces of equipment, is likely to be considerably more mobile to outsourcing environments such as China. Products embed technology within them, so that the users of the technology need not have the same level of skills as those who created it. On the other hand, process innovations, to be sustained across borders, require similar levels of skills in the outsourcing environment as in the country that developed the innovation. Later, we discuss how Japan's labor force is well positioned to innovate in products from the viewpoint of skills. The point we wish to stress here is that, by focusing on product innovations, Japanese firms could capture more value out of a product than by focusing on process innovation, since much of the gain from process innovation is difficult to realize in offshore locations.

Accordingly, the three pillars of the Japan model are not able to support the quasi-institutional structure of innovation, as it existed in the 1980s. The main bank system and cross shareholding have crumbled, leaving corporate stability nearly indistinguishable from other highly developed countries' experience, and lifetime employment applies to only a very small part of the labor force.

10.5 Empirical Evidence of Sustained Innovation in Japan

Nearly two decades of financial difficulty have not blunted Japanese companies' *potential* for innovation. Notably, however, the Japanese publics' and even thought leader's realization of that potential has been significantly muted. To examine why this is the case, we now examine the innovation strategies that characterized Japan's initial period of great success, and how the changes of the 1990s rendered those strategies inappropriate. This will set the stage for a discussion of the new innovation strategies that Japanese firms are employing, and their potential for maintaining Japan's innovative potential.

Recent empirical data demonstrate that Japanese firms have maintained a notable lead in common metrics of innovation. While there are no well-recognized and generally accepted measures of innovation, a comparative examination of Japan's scientific and technological knowledge base is a useful approach as Japan's current difficulties are often viewed in light of the rise of the rest of Asia, particularly China. Asian countries outside of Japan have made remarkable progress in developing their scientific and technical capabilities. As Fig. 10.5a shows, Asia outside of Japan now consists of over 10% of all US patent applications, with South Korea and Taiwan showing particular strength and China a very rapid rise. As Fig. 10.5b shows, Asia's rise goes beyond patenting to include more basic science, also. The number of scientific and engineering papers published by country has also seen steady gains, with China exhibiting an especially amazing rise.

However, including Japan data in these charts, as in Fig. 10.6, leads to an important perspective. Despite the growth in innovation elsewhere, Japan still produces more US patents than the rest of Asia combined. The situation is the same, albeit less dramatic, if one examines the growth of scientific and engineering publishing. Japan remains the dominant Asian producer of scientific and engineering papers.

Critically, Japan is strong in the fields that are commonly recognized as the foundation to future innovation. Figure 10.7 shows the number of US patents held by Japan and other Asian countries in four critical fields: nanotechnology, biotechnology, information and communications technology (ICT), and renewable energy.

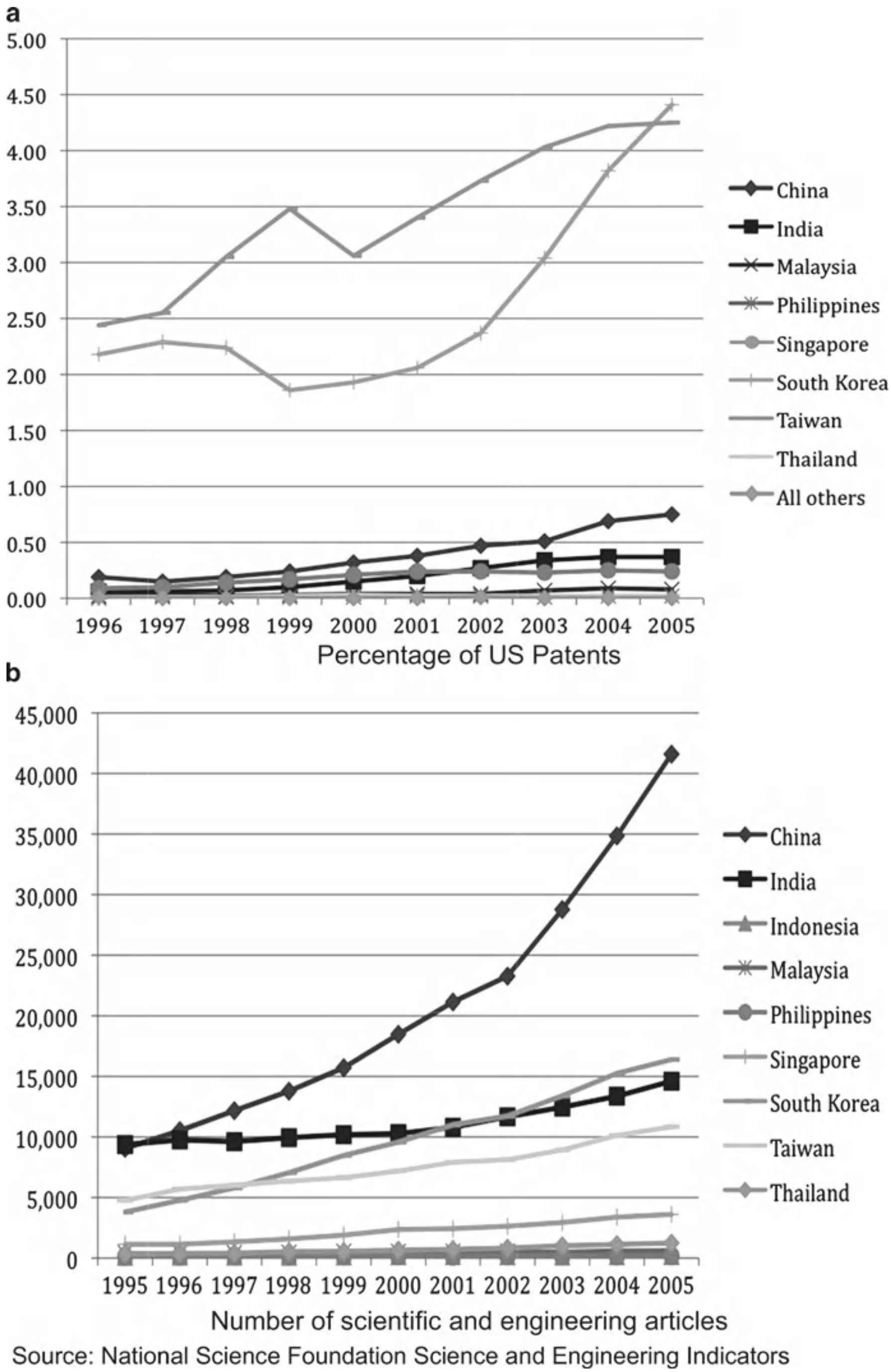

Fig. 10.5 Creation of scientific and technological knowledge in Asia, excluding Japan. (**a**) Percentage of US Patents. (**b**) Number of scientific and engineering articles (*Source*: National Science Foundation Science and Engineering Indicators)

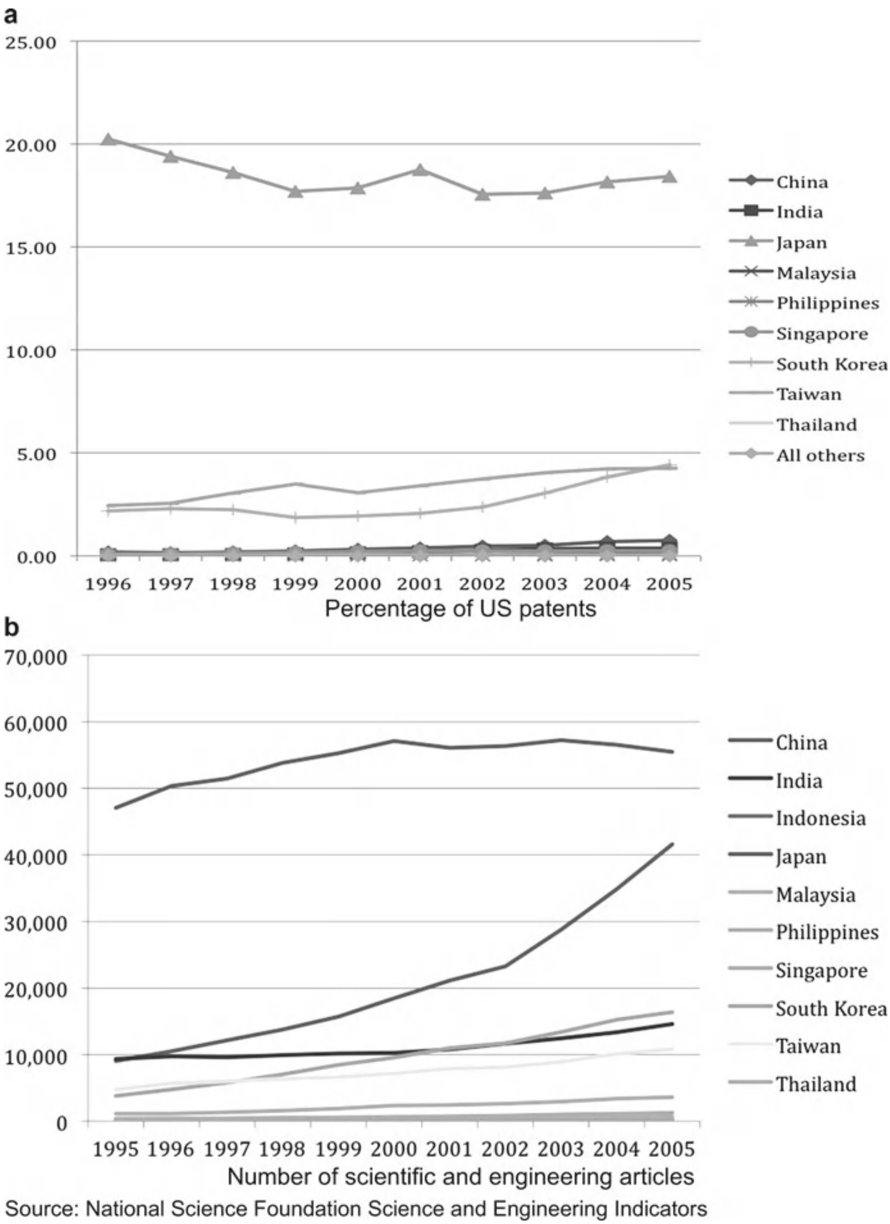

Fig. 10.6 Creation of scientific and technological knowledge in Asia, including Japan. (**a**) Percentage of US patents. (**b**) Number of scientific and engineering articles (*Source*: National Science Foundation Science and Engineering Indicators)

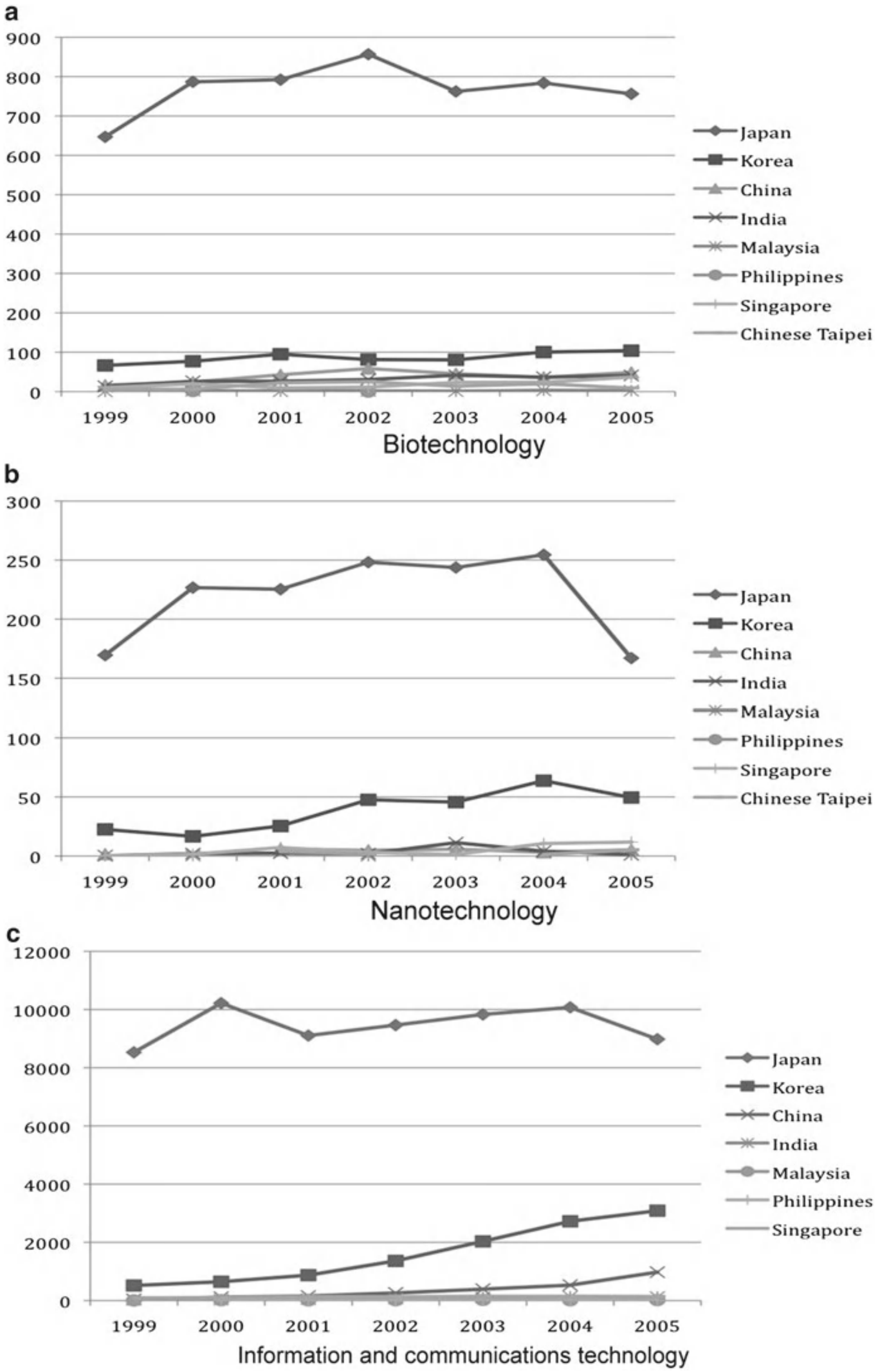

Fig. 10.7 US patents held in key fields of innovation. (**a**) Biotechnology. (**b**) Nanotechnology. (**c**) Information and communications technology. (**d**) Renewable energy (*Source*: OECD Compendium of Patent Statistics, 2008)

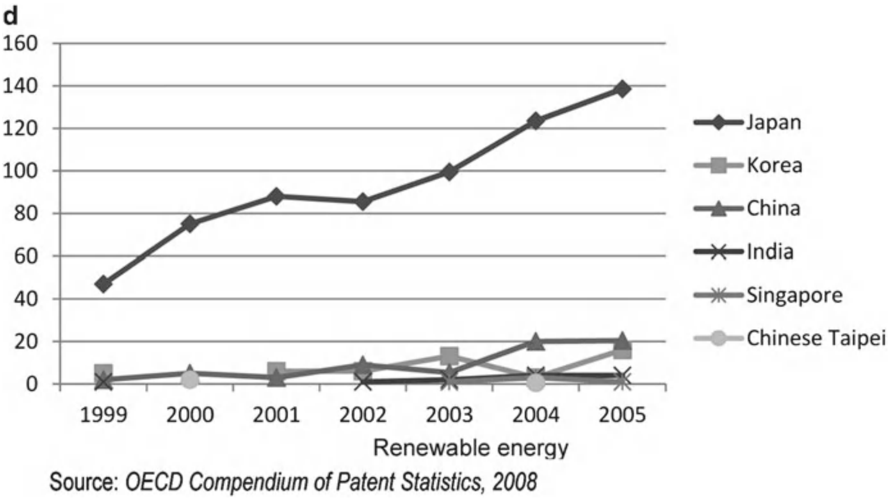

Fig 10.7 (continued)

10.6 The New Japanese Firm Innovation Strategies

The new institutional framework facing Japanese firms: the demise of the Japan model of business equilibrium, the changing labor organization, and the changing international dynamic from Asian development and the worldwide drive for efficiency meant that Japanese firms, seeking maximum competitive advantage, had to devise and follow new strategies to reflect the new rules of the game. Some writers are even finding that the financial and labor market reforms have greater potential for innovative development than the industrial policy efforts of the earlier equilibrium (Noland 2007). Nolan found evidence that the high level of regulation in markets influenced by industrial policy actually retarded innovation, so reforms would release their potential. Other authors find that university–industry linkages, usually modeled on American systems, hold promise for future innovation in the new economic contexts (Pechter 2001; Edgington 2008).

While this new literature is developing, it seems clear that firms have not yet, via the discovery of best strategies within the new institutional framework, found a common successor model. Within the varied strategies illustrated here, we find three major categories of innovation strategies that are found in the academic, policy, and business literature. They may be summarized as:

1. Path dependency in human capital development as a complement.
2. Innovation opportunities in new industries.
3. Innovation in new firms.

10.6.1 Path Dependency in Human Capital Development

An important foundation of Japan's innovative potential is its basis of human capital that developed in the post-war period. During the equilibrium before 1990, many authors noted the strategies that firms used to implement shop-floor innovation involved workforce education, training, and continuing education (Nagaoka and Flamm 2006). We take note of two indicators that show that, even as the institutional basis of the past innovation strategies were altered, the human capital development efforts have remained.

First, the prevalence of scientific and technical researchers in the Japanese economy (Fig. 10.8) exceeds that of other comparable nations. Whether one examines the number of researchers per 1,000 employees in the economy as a whole (Fig. 10.8a) or more narrowly within business enterprises (Fig. 10.8b), the proportion of Japanese employees engaged in innovation-creating research consistently leads the world. Despite the economic challenges faced by Japanese firms, they have continued to dedicate significant human resources to innovation. One explanation for this continued investment is a belief that, given Japan's relative high labor costs, investment in innovation is required to maintain competitiveness (e.g., see Dujarric and Hagiu 2009).

Particularly given low immigration rates, Japanese firm's innovation capability depend critically on its educational system producing highly educated workers. According to the 2006 OECD Programme on International Student Assessment (OECD PISA), Japan's 15-year-old students rank third among OECD countries in average science competence. Not only does the average Japanese student exhibit higher than average competence in science, but Japan has also a comparatively large proportion of top performers (2.6% in the highest level and 15.1% in the second highest level, compared to an OECD average of 1.3 and 9%, respectively).

Second, Japan has been similarly successful in producing students with a high degree of mathematical competence. According to the 2006 OECD PISA, the average rating for mathematics skills of Japan's 15-year-old students ranked sixth in the OECD. Again, Japan has an above-average proportion of top performers (18.3%) vs. the OECD average (13%).

Building on success at the secondary-school level, Japan is now second in the OECD (behind Canada) in the proportion of people with university-level or vocational tertiary qualifications. Interestingly, Japan ranks slightly below the OECD average in the number of science graduates (1,596 per 100,000 employed 25–34-year olds vs. the OECD average of 1675). This is almost entirely explainable by the low number of female graduates in the sciences, nearly the lowest in the OECD and only 24.8% the number of male science graduates. While troubling, this discrepancy can also be viewed as a potential opportunity. Given the uniformly high quality of Japan's math and science education at the secondary level, Japan could dramatically increase its number of science graduates by increasing the participation of women in science at the tertiary levels.

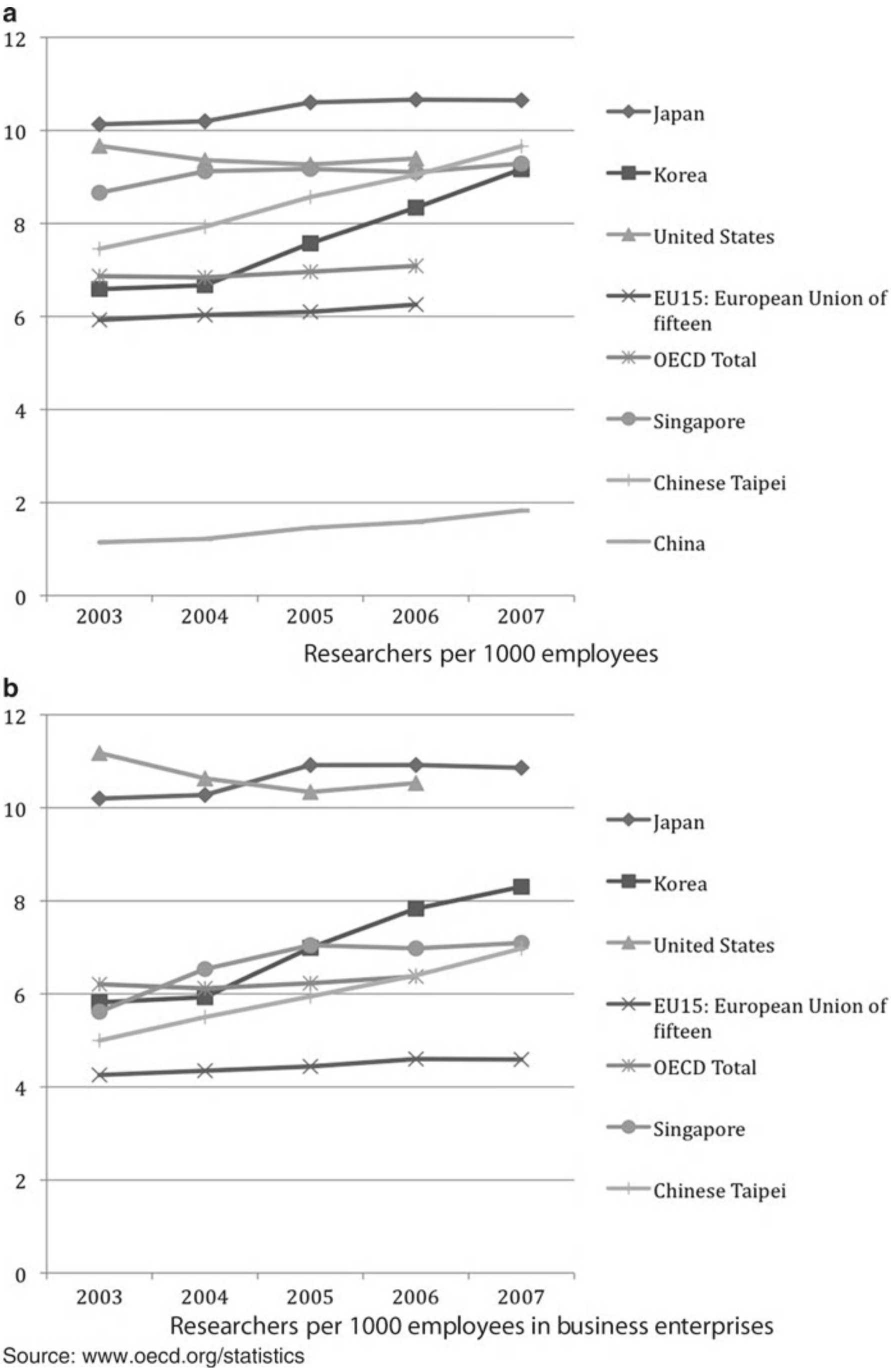

Fig. 10.8 Researchers in the workforce. (**a**) Researchers per 1,000 employees. (**b**) Researchers per 1,000 employees in business enterprises (*Source*: www.oecd.org/statistics)

10.6.2 Innovation Opportunities in New Industries

Due to Japanese firms' earlier status as technological innovators in telephony and other electronics, firms are now particularly well positioned to build upon their technological strength in the ICT (Internet, Communications, and Telephony) industry. Web-enabled services and products depend on the presence of a fast, inexpensive, and nearly ubiquitous network or Internet access. A long history of investment by Japanese firms has yielded one of the most sophisticated telecommunications infrastructures in the world. Although the penetration of broadband Internet access in Japan (23%) is just above the average of OECD countries, the quality of that access is exceptional. Japanese broadband customers enjoy the highest average speeds in the world (92,846 kb/s), which is almost an order of magnitude faster than the US average of only 9,641 kb/s. Broadband service in Japan is also inexpensive. The average monthly broadband subscription price in Japan is $30.46, the least expensive in the OECD excepting Greece and Sweden ($30.06 and 29.22, respectively). Japan's true advantage becomes evident when pricing is adjusted for available speed. Japanese consumers pay on average $4.79 per Mb/s, less than half of what US consumers who pay, on average, $10.02 per Mb/s.

One reason for the efficacy of Japan's telecommunications infrastructure is the prevalence of fiber-optic, rather than copper, cable. Fiber constitutes ten percent of broadband access on average across the OECD. In Japan, 48% of broadband access is via fiber, leading second-ranked South Korea (40%). Fiber is important because it offers much higher capacity than copper. Furthermore, it is much easier to upgrade and expand, meaning that networks in place today will form the basis of newer technologies for the next 25 years.

Therefore, the presence of an extensive fiber-optic network provides the infrastructure required for innovative Web-based applications that are data intensive, such as multimedia applications. Indeed, the presence of fiber may actually increase demand for such service. A recent study in Europe found that households with broadband access via fiber-optic networks generated three times more traffic than those using the fastest copper networks. This has occurred even though "dedicated mass-market fiber applications are not even available yet."

Japanese firms are also well positioned to take advantage of opportunities in the field of environmental technologies, including renewable energy. In this, Japan's oft-cited lack of natural resources, particularly fossil fuels, may have proven a competitive advantage. As noted above, Japan has significant technological strength in this field. More importantly, it has already achieved significant success in applying these technologies.

This success is indicated in Fig. 10.9, which compares common indicators of environmental innovation to other nations in East Asia. As shown in Fig. 10.9a, Japan is a leader in the use of clean energy, producing almost 17% of its total energy production from clean sources. Japan is also extremely efficient in its use of energy. Figure 10.9b presents a measure very relevant to economic competition, the dollars of GDP produced per unit of energy use. At $7.32 per kg of oil equivalent (2005 PPP dollars), Japan is more than twice as efficient in translating energy into GDP as China. It is 21% more efficient than its closest regional competitor, Singapore.[1]

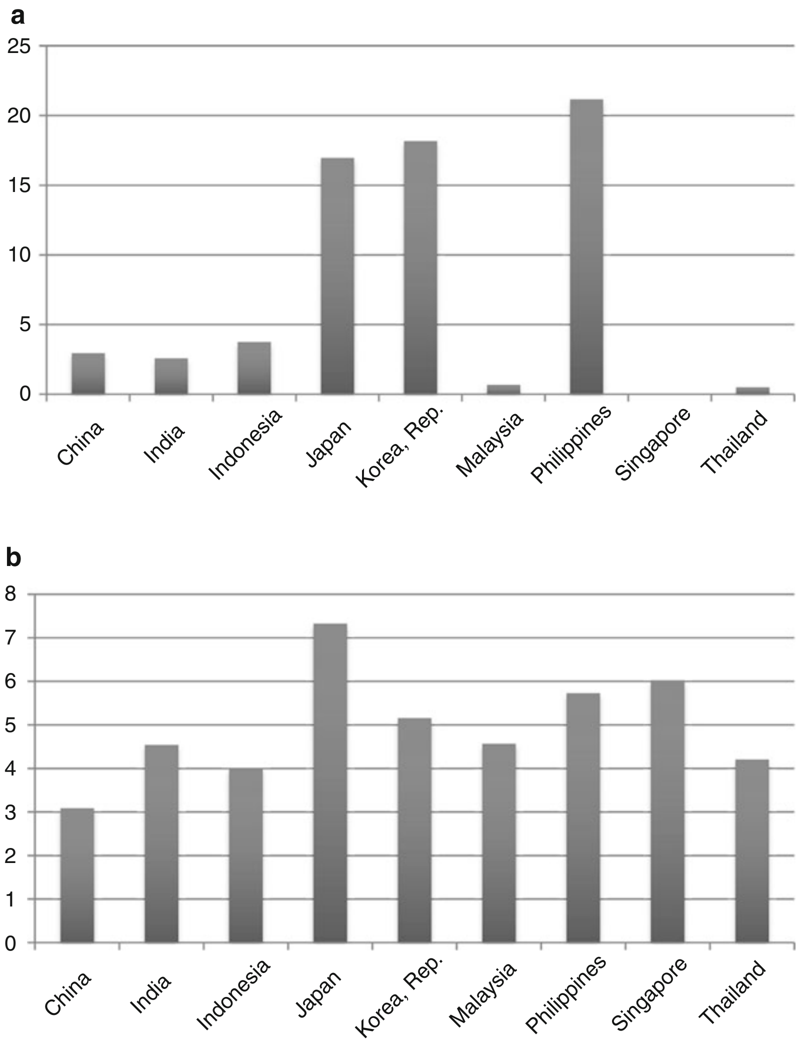

Fig. 10.9 Indicators of environmental innovation. (**a**) Clean energy production (% of total energy use). (**b**) GDP per unit of energy use (constant 2005 PPP $ per kg of oil equivalent). (**c**) CO_2 emissions (kg per PPP $ of GDP). (**d**) PM10, country level (micrograms per cubic meter) (*Source*: World Development Indicators, World Bank. Data from 2005)

[1] As an indication of the efficiency of Japanese manufacturing, Japan's advantage remains substantial after scaling for the percentage of (less polluting) services in the economy (Japan 68% of GDP, China 40%, and Singapore 68% in 2006, according to World Bank figures).

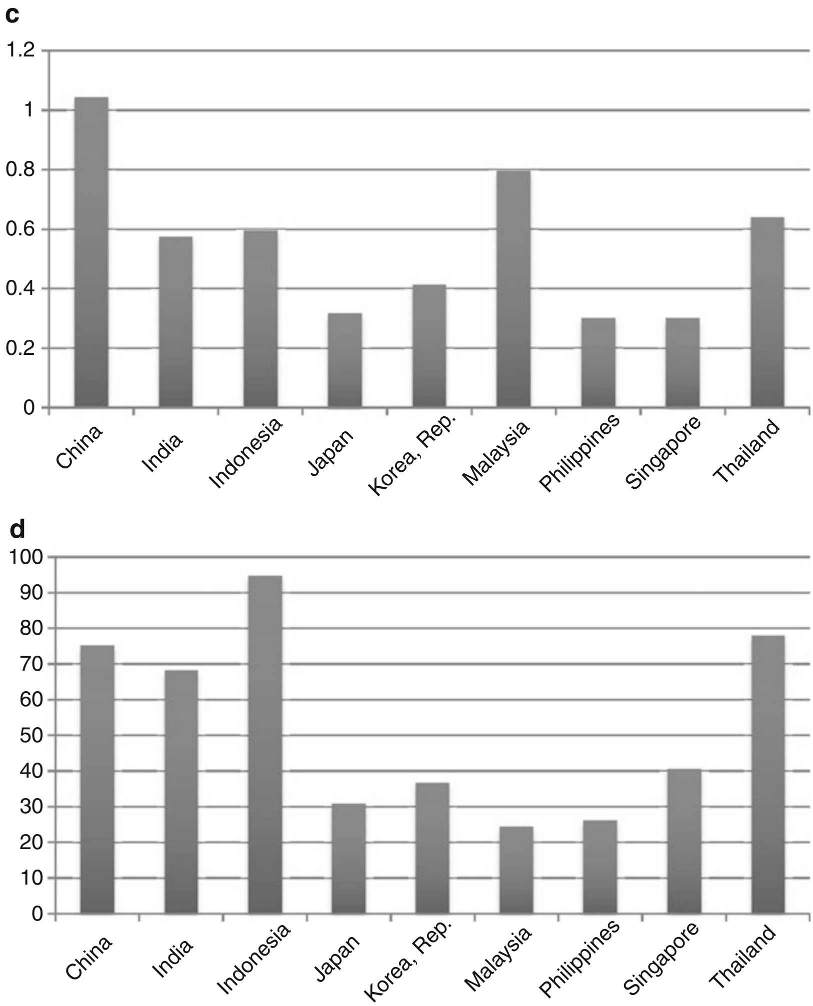

Fig 10.9 (continued)

The combination of energy efficiency and clean energy production has yielded apparent benefits for Japan. As Fig. 10.9c shows, Japan produces a very low amount of CO_2 for each dollar of GDP. Combined with the application of other environmental technologies, it has allowed Japan to maintain very high air quality. Fig. 10.9d reports the PM10 measure of air pollution. PM10s are the suspended particulates small enough to enter the lungs and cause significant health damage (under 10 μm) (Organization 2004). With approximately 31 μm/cubic meter, Japan is well below the EU's legislated limit of 40. It is also a regional leader, with less than half the air pollution of China, India, Indonesia, and Thailand.

Thus, Japan is a regional technology leader in a sector that will see increasing demand worldwide. In particular, Japan's geographic proximity and extensive investments position it to play a major role in China's market for green technologies, which some see growing in value to between $500 billion and $1 trillion (Areddy 2009).

10.7 Innovation in New Companies

Japan governmental organs developed new policies and financial systems to encourage "IT" companies, and a legion of small, technologically focused companies formed and became successful. Softbank, Value Commerce, Rakuten, Livedoor, Mixi, and Cybird are just a few of these companies, some of which made their founders famous and became enviable places to work. There is now evidence that small, new companies accomplish a not insignificant and increasing share of innovation in Japan.

The data from METI's most recent survey of new company formation showing a trend in ICT and software start-ups are associated with legal changes enacted to encourage start-ups. Within the past 10 years, many laws have been enacted to promote entrepreneurship and thus innovation. Just some of these are:

- Allow the money needed to establish a stock issuing company to be lowered from ¥10, 000,000 to 1.
- Revise the bankruptcy laws to allow the directors of bankrupt companies to retain much of their personal assets.
- Encourage mergers through a series of laws, including the loosening of regulations surrounding triangular mergers.
- Allow limited liability companies to exist to encourage venture capital firms to form.
- Giving tax breaks to "angel" investors.

New company formation rates in the ICT industry are comparable to US rates, long considered the standard in this regard. There is now evidence that small, new companies accomplish a not insignificant and increasing share of innovation in Japan. For example, in the biomedical industry, recent data show that biomedical patents from new companies now account for 23% of total patents, up from 4% in 2003 (Kneller 2007).

10.8 Conclusions

In this chapter, we have shown that Japanese firms in the twenty-first century maintain a high rate of innovation and are entering new fields of business. This is occurring even though the institutional support of innovation for Japanese firms extant in the 1980s has undergone important changes.

The main bank contingent governance system, the stable labor markets, and long-term business relationship have been destabilized by economic realities after the collapse of Japan's asset bubble in 1990. In the past, these three factors contributed to both the incentives to raise the level of human capital and to the long-term stability of the economic context within which firms operated. Main bank contingent governance ensures long-term shareholding and leads to a stability of expectations from capital. Long-term business relationship and long-term employment similarly tended to ensure stability of corporate behavior. In the old environment of stable, long-term ownership, management, and employment, a firm generated high returns from improving labor and management productivity within the constraint of keeping employment constant. Strategies that raise productivity while reducing staff were unacceptable. The former is more consistent with process innovation, while the latter is equally consistent and – more importantly – complementary to product innovation.

Japanese firms, in the former equilibrium, depended heavily on the strategy of human capital development. We find that through path dependency, Japanese firms maintain their reliance on this key strategy, and, perhaps serendipitously, that this strategy is complementary to product innovation. Certainly, Toyota and other large Japanese firms maintain many aspects of strategic responses to the earlier environment, and, accordingly, produce incremental process innovation to maintain a competitive edge (see Osono et al. 2008). Now, it seems clear that the habits of human resource development may complement the more recent demands of product innovation.

Through continued development of human capital, Japanese firms can mitigate the effects of changing demographics by making each employee more productive. This also serves the needs of a company improving its competitive position through new product innovation. Further, the new, entrepreneurial companies that are beginning to flourish in Japan have a tremendous resource in the well-educated and trained workforce.

Japanese firms have a well-deserved reputation for innovativeness in a developed and dynamic economy. As Milhaupt and West commented in 2004, Japan could not maintain its remarkable position as the second largest economy for decades without being both innovative and entrepreneurial (Milhaupt and West 2004). The data seem to confirm that institutions of the past may account for some Japanese firms' strengths.

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Chapter 11
Preparing India's Workforce for the Knowledge Economy

Rafiq Dossani and Murali Patibandla

11.1 Introduction

Even as of 2000, the idea that India would, in less than 5 years, compete in the global services economy would have seemed farfetched. Although it had by then a recognized (though small) presence in software exports, the Indian services sector was, overall, like other emerging countries. In such countries, services are largely provided by small, low-technology enterprises catering to the local economy.

As of 2009, the services sector is both driving economic growth in India and a formidable global competitor. Services comprise 54% of GDP, growing at a near 10% rate. Of course, most services remain small, low-growth, low-technology services and are a form of disguised unemployment; many will reduce in importance as manufacturing strengthens. But several high-growth services are sophisticated services, representing a turnaround from the past. Telecommunications services, for example, were of poor quality and generated negligible revenue in 2000. A decade later, India's telecommunications sector is among the world's most sophisticated, with redundant fiber-optic networks that reach almost all settlements, including India's 600,000 villages; a wireless network that adds more customers each month than China; and, a sector that contributes over 5% to the GDP. Airlines and financial services are other such domestic services.

The services sector for which India is world renowned is the IT-enabled services sector. From less than 1% of the GDP in 1997, India's IT-enabled services exports comprised 3.6% of the GDP in 2006 and 4% in 2008. The value of these exports

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rose from $1.8 billion in 1997 to $32 billion in 2006 and to $47 billion in 2008, an annualized growth rate of over 35% till 2006, although the rate fell to 20% thereafter, in large part due to the global slowdown (NASSCOM 2007:54, 2009:6). With this, India left other developing and even some developed countries far behind in their ambitions to become leaders in services exports.

The term "IT-enabled services" might not convey to the reader the range of services that are exported from India. They potentially include any service that can be delivered electronically using digital technologies. While, initially, the exports were confined to software programming and, later, call centers, after 2000, the range and depth of work changed dramatically. The list, as of 2009, includes scientific research and development, financial services, market research, data mining, and a host of other services. Largely, the services are located in the vertical termed "professional, scientific, and technical services."[1]

The Indian success with remote services' provision disproves a widespread belief that Asia is better at manufacturing than services. This shibboleth is based on the evidence that even the advanced economies of Asia, i.e., Japan, Singapore, Taiwan, Hong Kong, and Korea, failed to create globally competitive service industries. In a range of other key services, such as software, retailing, telecommunications, logistics, and insurance, no Asian global brand names exist. The common understanding behind this belief is that acquiring advanced services skills is not an easy or short-term task.

Instead, Asia's economic growth was driven by manufactured goods' exports. This was based on the application of large inputs of physical and financial capital (Krugman 1994).

Yet, this is not true of India. Further, Indian firms such as TCS in software services and the Taj group in hotels are beginning to be recognized as brand names. Along with this, the provision of global services is growing in scale, scope, and depth at rates that are increasing India's lead over potential competition (Dossani and Kenney 2007).

This chapter examines the contribution of higher education to this success. The quality of a nation's higher educational system is a key driver of new product and service development, the theme of this book. Emerging economies such as India cannot afford to import trained manpower and, so, must develop their own. But, they face significant challenges. In practice, higher education is the outcome of a complex partnership between the nation's state and its citizens. In some cases, the state takes a leading role, such as in determining budgets for higher education and

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[1] The US government's NAICS code 54 defines the sector: "The Professional, Scientific, and Technical Services sector comprises establishments that specialize in performing professional, scientific, and technical activities for others. These activities require a high degree of expertise and training. The establishments in this sector specialize according to expertise and provide these services to clients in a variety of industries and, in some cases, to households. Activities performed include: legal advice and representation; accounting, bookkeeping, and payroll services; architectural, engineering, and specialized design services; computer services; consulting services; research services; advertising services; photographic services; translation and interpretation services; veterinary services; and other professional, scientific, and technical services." http://www.census.gov/epcd/naics02/def/NDEF54.HTM, June 11, 2007.

allocating responsibilities between the federal and state governments; in other cases, such as determining research goals, both the state and nonstate sectors may help to determine outcomes.

For decades, India struggled to develop a higher education system within the public sector capable of meeting the country's needs for a trained workforce. It was not alone. Prior to the fundamental changes that swept higher education systems globally in the 1990s, leading to massification and privatization, state-run higher education systems were the norm across the world and faced challenges relating to access, coverage, price, and quality. A telling phrase used by Cohen et al. (1972) describes higher education systems as "organized anarchies," where goals are problematic rather than generally agreed upon, where links between cause and effect (particularly over governance arrangements) are unclear, and where decision making involves an everchanging cast of characters rather than a fixed group of participants operating within clear institutional boundaries.

Before we shift attention to higher education, we attempt to provide some perspective by examining some other factors that enabled the success of India's global services sector.

The first is the way that the world economy developed. The previous paradigm of services spatially tied to core nationally based manufacturing activities was replaced by one based on the provision of globally tradable services. This gives countries with advanced services skills an advantage. India's turn toward services, in part because of policies that restricted manufacturing, preceded other low-cost countries that were still intensely involved in harvesting manufacturing. This gave India a first-mover advantage that it has continued to capitalize on.

Second, some attribute India's success in providing technical services to technology itself. As documented elsewhere (see Dossani and Denny 2007; Dossani and Kenney 2007) the technology for the remote provision of services changed dramatically in the past decade. The Internet and lower digital storage costs combined to reduce the capital costs associated with remote service provision, while modularization of software preparation and other services reduced the operating costs of remote provision.

The impact of the first-mover advantage should not be overstated. India was not the first mover in global service provision from a low-cost country. Many Asian countries entered global service provision much earlier than India, such as Japan and Korea with their banks in the 1980s, with limited success.

Likewise, regarding the enabling power of technology, many other countries – in east Asia and southeast Asia, for instance, had similar or better access to the latest technologies earlier than India. Their infrastructure, capital access, and scale of global trade were far superior to India. Had technological change been the only enabler of services, these would have captured the business a long time before India was even an entrant.

The explanation for India's success is, therefore, unlikely to be a simple one. However, as the foregoing discussion indicates, it is likely to lie in some dimension of human capital rather than physical or financial capital. Unlike manufacturing, where it is possible to produce high-technology products by applying relatively unskilled labor to sophisticated machinery, skilled services, by contrast, cannot be provided by combining unskilled labor with physical and financial capital. By definition, the providers of "just-in-time" skilled services such as IT help desks need to be as skilled as the service provided.[2] Even many "storable" services such as software code require skilled labor.

Several skills appear to be relevant. Indians' most obvious advantage over other low-cost providers is that a relatively large number of people, perhaps as many as 50 million, speak fluent English. Many of them were underemployed till the 1990s due to India's closed economy. Once India opened up its economy in the 1990s, it is argued, this became an asset.

However, this "late-mover but English speaking" advantage is unlikely to be the only or even the main reason for India's success. Many countries' citizens speak equally fluent English, where wage rates are comparable, which globalized earlier than India, and yet failed to become global service providers. The Philippines, which opened its economy to global trade two decades before India, is an example.

On the other hand, although it is hard to come by examples in the developing world, firms in developed countries where English is not widely spoken and which yet succeeded in other Western markets are common. SAP of Germany is one example, and several others in services such as IT, retailing, and logistics.

A second aspect is higher education, including technical education. The need for such an education is no longer doubted by development analysts and policymakers (World Bank 2000:12). Several reports show that India and China are producing a large number of students who are skilled in particular vocations, particularly engineering. Some of these reports also question the quality of the students (Wadhwa et al. 2007).

Even if the number is high and the quality is good, it is not obvious that this "scale-and-depth" factor is sufficient for success. As the following table for the software industry shows, neither size nor stage of development is sufficient to explain a country's success.

The table shows that some countries such as Japan, with a large and high-quality software labor force, were unsuccessful at global software provision; countries, such as Brazil and China, with a large software labor force, and a more uncertain quality of engineers, were also unsuccessful. On the other hand, Ireland and Israel have small labor forces and are successful (Table 11.1).

A third dimension is that the type of human capital needed is changing rapidly. In the field of engineering, for instance, the social science aspects of engineering education, such as business and entrepreneurial courses for engineers, may be as important as teaching engineering skills. Merely developing a large number of traditional engineers is much less relevant today than in earlier industrial development. Perhaps India succeeded in a transformation of the nature of engineering and science education so that engineers possess "scope" in addition to depth. Our preliminary analysis of these factors, however, is not encouraging (Table 11.2).

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[2] We are grateful to Frank Mayadas for this key insight.

Table 11.1 Software exports from developing countries, 2001

Country	Sales ($ billions)	Exports	Labor force (2000)	Sales per employee ($'000)
Brazil	7.7	0.1	220	35
China	7.4 *(15.0)*[a]	0.4 *(2.0)*	186 *(750)*	40 *(20)*
EE5 (Bulgaria, Czech Republic, Hungary, Poland, and Romania)	0.6	0.5	75	8
India	8.2 *(22.3)*[a]	6.2 *(17.1)*	350 *(878)*	23 *(25)*
Ireland	7.7	6.5	24	160
Israel (2000)	3.7	2.6	35	106
Japan	85.0	0.07	535	159
The Philippines	0.2	0.15	0.05	12
Russia	0.2	0.1	0.1	13
United States (2002)	200.0	NA	2,600	77

Sources: Arora and Gambardella (2005:45, 77, 101); Sahay et al. 2004:17; NASSCOM (2006:46, 47)
[a]Figures in italics are for 2005

Table 11.2 Allocation of time, for Indian students at engineering colleges

	Indian engineering colleges	Stanford University
Lecture: Laboratory hours	3:1	3:1
Supervised: Unsupervised	3:1	1:3 (years 1 and 2) 1:4 (years 3 and 4 – major) 1:2 (years 3 and 4 – other)
Total hours/week: Major	40	24 (years 1 and 2) 50 (years 3 and 4)
Total hours/week: Other	3	36 (years 1 and 2) 15 (years 3 and 4)
Lecture: Small-group hours	2.3:1	1:3
Total units in major (including prerequisites)	88%	52%

Source: India data from survey of 732 students in eight Tamil Nadu colleges; Stanford University data from survey of graduating computer science students. Survey undertaken by Carnoy M and Dossani R 2008–2009

Our above discussion implies that India's success is possibly due to some combination of first-mover advantages, English-language skills, scale, depth, and scope. Examining all of these in sufficient depth is outside the scope of this chapter. Instead, this chapter focuses on one discipline, software engineering, and limits its scope to an assessment of technical education. The questions we pose are whether some fundamental aspects of the education system for technical education, such as governance, enabled India to succeed as a service provider to date and whether these aspects will enable India to continue to provide the quality of manpower it needs. The fundamental aspects are defined in more detail in Sect. 11.3.

This chapter is divided as follows. In Sect. 11.2, we discuss the education system in India – policy, scale of provision, role of different providers, etc. In Sect. 11.3, we provide a theoretical model of factors that influence quality. In Sect. 11.4, we provide our methodology of assessment and sources of data. Section 11.5 provides the results of our assessment. Section 11.6 provides a concluding discussion.

11.2 The Education System in India

11.2.1 The Role of the State

India has a federal constitution, under which education is a "concurrent" subject, i.e., a joint responsibility of the federal (central) government in New Delhi and the states. The division of responsibilities is clear in some cases and not as clear in others. The central government, it is agreed, is solely responsible for determining standards for teaching and research. The state governments are supposed to establish universities and colleges that meet these standards, allow private colleges to affiliate with universities, and are responsible for the universities' funding and management. Note that the university in the Indian higher education system has a different meaning than in America. Indian universities are largely "affiliating" universities at the undergraduate level. They do not offer their own courses but prescribe to the affiliated colleges the course of study, hold examinations, and award degrees. The colleges hire teachers, recruit students, and educate them.

About 80% of the funding for higher education is provided by the states and 20% by the center through various bodies such as the University Grants Commission (see below). Coordination between the central and state governments is done by the Central Advisory Board of Education (CABE).

The division of responsibilities between the federal and state governments started to overlap when India's first Prime Minister, Nehru, ordered the federal ministry of education to establish universities directly controlled by the federal government. This was because Nehru was keen to speed up the quality of technical education in order to realize his vision of the country as an industrial superpower. He felt that this needed direct supervision from New Delhi rather than by the states. The Indian Institutes of Technology (IITs) were an outcome of that vision. As of 2009, there are 18 federally run universities of a total of over 300.[3] They offer a higher quality of education than state universities for several reasons, including superior funding. The policy direction of selectively creating new federal universities continues to the present day, because it is still policymaker opinion that the best institutions can only be created by federal-level oversight.

Most university education, however, continues to be provided by the states. This creates the lack of a quality continuum. The generously funded central universities occupy the upper-quality tier and the state universities are, in general, significantly

[3] This includes some colleges that have obtained the status of deemed universities. These are undergraduate teaching universities, unlike the typical system of affiliating universities.

Box 1 The Importance of the IITs

Perhaps the best known Indian engineering institutions, both within and outside India, are the state-owned Indian Institutes of Technology (IITs). These were established by the federal government starting in the mid-1950s. Recruiters around the world recognize the IITs as a global-class brand.

The IIT system is emblematic of not just the best but some of the worst aspects of the Indian education system. The best is that the seven IITs produce a quality of undergraduate student that is, as noted, of global class. They do this through a fourfold strategy: selective, merit-based recruitment (over 250,000 applicants vie for less than 5,000 seats each year),[1] low tuition costs (tuition costs are less than $1,000 per year),[2] commitment to teaching excellence, and adequate infrastructure.[3] The first two strategies lead to a high quality of student admitted, while the latter two strategies cause high value addition in undergraduate education.

These strategies represent a compromise between state and institutional interests. The admissions procedures, for instance, are based on rules that are common across the IITs. The student's prior academic performance and, most important, her performance in a common entrance examination administered jointly by all the IITs determine whether she will find admission. The contents of the entrance examination are, however, determined by faculty.

The faculty selection procedures are more flexible, with considerable autonomy given to the departments, although final letters of appointment require the approval of the head of the institution. Departments also determine curricula and pursue linkages with the corporate sector.

In all other aspects, the IITs are under the state's control. This has resulted in an overly rules-based and often corrupt administration that stifles academic freedom to pursue research or design new courses.

The worst aspects of the IIT-system are, first, the absence of a second tier of quality below the IITs. There are the IITs, then about a dozen other state-owned institutions of repute and then a vacuum.[4] The mass of the state-run

[1] Source: http://www.hindu.com/2007/04/09/stories/2007040901761300.htm, June 11, 2007.

[2] Source: http://www.iitm.ac.in/academics/Academic%20Calendar.html, June 11, 2007.

[3] The general quality of infrastructure, research, and university-industry linkages is a particularly difficult problem. According to a government report, "obsolescence of facilities and infrastructure are experienced in many institutions… the IT infrastructure and the use of IT in technical institutions is woefully inadequate… the barest minimum laboratory facilities are available in many of the institutions and very little research activity is undertaken… engineering institutes have not succeeded in developing strong linkages with industry… the curriculum offered is outdated and does not meet the needs of the labor market" (Indian Ministry of HRD, 2001, Sections 2.1.2–2.1.6).

[4] http://www.dqindia.com/content/top_stories/2006/106062703.asp, June 11, 2007.

(continued)

Box 1 (continued)

and private institutions are third tier. A shortage of funds is the main reason for the quality vacuum. Second, the current dynamics of the higher education system threaten the quality of the IITs. The staff at the IITs and other state institutions are being cannibalized by private institutions due to salary caps, the IITs' research output is meager to nonexistent (matched by a minimal output of graduate students) due to a lack of academic freedom and incentives, and collaborations with industry for training students are minimal.

The IITs offer important lessons on how a country can provide a high standard of education for a small cohort chosen on merit. First, it can be done quickly. The IITs were begun in the 1950s and achieved excellence within a decade. This was partly due to overseas collaborations in the initial years for the purposes of curriculum and faculty development. The country's best faculty and student applicants turned to the IITs simply because it offered the best students, teachers, and infrastructure. Over time, the four strategies noted above emerged.

One lesson from the IITs' success is that while a rules-based process of admissions might not be optimal in a more mature environment, it might make sense in a less mature environment. It protects the institution from misuse that might arise if more discretion is given to the institution. Of course, it raises the question of how an institution is to transition to a less rules-based system that might be desirable as the environment matures.

Another lesson is that so long as the state does not interfere in faculty selection, or in curriculum development, and finances equitable access and infrastructure, its other dimensions of control will not, at least for a time, be a fatal deterrent to the provision of a good undergraduate education.

behind. This feature also restricts the natural flow of the best students to successively higher tiers within state-level institutions. In the U.S., a community college student can end up within 2 years in a top-tier state university by performing well in community college. This is not possible in India.

The federal government exercises its responsibility for setting and maintaining standards through an apex body, the University Grants Commission, established in 1956, that is "responsible for coordination, determination and maintenance of standards and the release of grants" (http://www.education.nic.in/higedu.asp, accessed May 29, 2008).

The UGC relies on professional councils set up by the federal government to recognize colleges and universities and courses. The councils also channel UGC grants for undergraduate education, while UGC directly funds other aspects of public higher education, such as research and general budgets. The council that manages IT education is the All India Council for Technical Education (AICTE).

11.3 Degrees

The primary higher education degree is the bachelor's/undergraduate degree.[4] For professional fields, including engineering, this requires 4 years of study after completing 12 years of primary and secondary school. Some professional fields, such as medicine and architecture, require 5 years. For other fields, such as arts, commerce, and physical and social sciences, the bachelor's degree requires 3 years of study.

The next higher level is the master's/graduate degree, which requires 2 years of study beyond the bachelor's degree. In engineering, admission to graduate programs requires taking a standardized aptitude test, the Graduate Aptitude Test in Engineering. Due to the recent high demand for software engineers, the UGC approved an unusual degree course a few years ago, the master of computer applications (MCA). The MCA is a 3-year graduate program, typically taken by those with nontechnical undergraduate degrees. Most upper-tier recruiters such as Google will typically not recruit a student with an MCA because such a student will not have undertaken the fourth-year design projects.

The highest level is the doctoral degree which typically requires at least 3 years of study after the master's degree and a thesis based on original research.

Nondegree courses include vocational courses leading up to a diploma. These are typically 1- to 2-year courses.

Only a university recognized by one of the central government councils may award a degree. Almost all the country's universities are publicly owned. As noted above, most universities are largely "affiliating" universities at the undergraduate level. They do not offer their own courses but prescribe to the affiliated colleges the course of study, hold examinations, and award degrees. The colleges within a university may be privately or publicly owned. Since 2005, some colleges that are of high quality have been declared "autonomous colleges." In these, the responsibility for proposing and developing courses of study lies with the college, while the university must approve the courses as eligible for degree-level instruction. The degree awarded in such cases is still by the university, although it also bears the name of the autonomous college. Since 2007, some colleges have been approved as "deemed universities," thus giving them complete autonomy.

Although private higher education was a feature of the system from the beginning, it became important only over the past decade. The change was policy driven. Prior to 1991, the state took the view that higher education should only be provided by the state. However, the country saw low rates of enrollment that were attributed to exclusive state provision. India's gross enrolment ratio, i.e., the number of age-unadjusted enrollees as a share of the eligible population that goes to university is, as of 2008, only 12% compared with 35% who complete secondary school. While

[4] We shall use American terminology in this chapter. A bachelor's education in both India and the US is referred to as an undergraduate education. A bachelor's degree is referred to in the US as an undergraduate degree, in India as a graduate degree. A master's education and degree is referred to as a postgraduate education and degree in India and a graduate education and degree in the US.

the absence of private provision did not always lead to rises in enrollment in other countries (see Appendix 1) – for instance, the state might reduce its commitment to higher education as a result, in India, it prompted a policy initiative since 1991 to increase the share of private provision. The other driver of private participation was the policy decision to reverse the historical bias of the state's education spending in favor of tertiary education. Historically, the government spent about 3–4% of GDP on education, and this accounts for 13% of public spending (Hiromi 2006:8). These numbers are comparable to many other developing countries, including China. About 15% of the total budget (equal to Rs. 120 billion or $3 billion in 2004) is spent on higher education (Nuepa 2006:23). Of this, about a fourth is spent on technical education (Nuepa 2006:5). On a per capita enrollment basis, however, the amount spent on tertiary education is three times that spent on primary and secondary education combined. By contrast, in China, about two-thirds, on a per capita enrolment basis, is spent on primary and secondary education.

About 700,000 students were enrolled in undergraduate degree courses in engineering (all fields) in 2003. This has risen rapidly in recent years and is, as of 2008, estimated to be 1.25 million (Nuepa 2008), giving India one of the highest growth rates (see Appendix 3). According to NASSCOM (2007:92), the number of new undergraduates in engineering was expected to be 264,000 in 2006. The IT workforce was further bolstered by those with engineering diplomas (usually a 2-year course, as noted above) (196,000 new diploma holders in 2006) and those with a master's degree in computer applications (MCA) (35,000 new awardees in 2006).

11.4 Private Providers

The impact of private provision can be seen in the following data: from a negligible presence up to 1990, as of 2005, they accounted for half of total undergraduate enrollment of about ten million students and over 60% of the number of degree-awarding institutions (see Appendix 1). Thus, much of the growth in overall enrollments in higher education is due to private providers. In more commercially lucrative fields such as engineering, they accounted for over three-fourths of the number of institutions.

Accredited private providers must, by Indian law, be organized as nonprofit institutions. They can be of two kinds: self-funded or government aided. The latter forces them to offer government pay scales to teachers and charge government tuition rates for admission.[5] In return, the government funds all costs in excess of tuition receipts. Almost all new private colleges since 2005 are self-funded.

[5] A recent trend is the private provision of foreign degrees in India by foreign universities operating in India. This, being outside the Indian education system, is little documented although its impact is believed to be small. It consists largely of little-known institutions in the western world charging high fees for degrees awarded by the foreign universities. By many accounts, most of these are "fly-by-night" operations.

The legal requirement of nonprofit status for private institutions means that they are invariably established as non-profit societies and trusts. This allows them to make profits provided these are plowed back into the institution. Of course, in practice, given India's murky record with tracking and disciplining malpractice, many, probably the vast majority (Nuepa 2006:43), suck large sums away through devices such as charging upfront "capitation" fees that are not tracked, employing family members of the trust's founders at enormous salaries, and so on.

The private providers have focused on the more lucrative fields such as engineering and management education, as noted above. As a result of their presence, the Indian higher education system has become increasingly differentiated. The private providers tend to specialize in only a few fields for which demand is high. By contrast, the state providers offer a wider range of studies.

11.5 The Quality of Education: A Theoretical Framework

11.5.1 The Role of the State

The quality of a nation's higher educational system reflects, as noted earlier, a complex partnership between the nation's state and its citizens. For instance, we earlier discussed examples where the private sector takes on roles that the state is either unwilling or incapable of doing, or needs partners for. In some cases, the state takes a leading role, such as in determining budgets for higher education and allocating responsibilities between the federal and state governments; in other cases, such as determining research goals, both the state and nonstate sectors may help to determine outcomes.

Even in an environment in which private provision thrives, as in the U.S., the state's role is critical. The ways that the state plays a critical role include the financing of education for efficiency and equity, directing science and engineering courses toward problem solving and creative thinking, and organizing the policy environment, governance structures, and institutional administration to produce higher quality training (Martinez 2002).

The policy decisions primarily concern the mix of teaching and research and the focus is on accessibility by targeted student populations. Depending on the charter of the institution and the environment (including competition), the role of the state in determining policy can vary.

The governance structures indicate the formal and informal arrangements allowing higher education institutions to make decisions and take action on strategic variables that influence the outcomes of these policies, such as setting fees and managing costs (World Bank 2000:83). The state, in many cases, not only determines policy priorities but may tightly govern the institution as well. For example, it may limit the freedom to pursue research, or regulate fees and costs. We term such a state role as "regulatory." In other cases, the state does not take an active role in defining policy, controlling the strategic variables, or ensuring that these are met.

However, it may still finance deficits. We term such a state role as "advocatory." In between the advocatory and regulatory states, the "steering state" helps to set policy priorities but leaves it to the institution to establish and manage the governance structures that will help to realize those priorities. This may happen even while the state finances deficits.

The administrative structures refer to rules and regulations that create the incentives for meeting the strategic choices. Examples are the rules for resource mobilization or terms of tenure. These may be bureaucratic, i.e., rules based, or, if not, subject to faculty influence or other influences such as donors and trustees. The state's role, if present, is usually higher when the administrative structures are bureaucratic and lower otherwise.

Obviously, the role of the state in a particular institution is constrained by the dependence of that educational institution on the state for resources and on the charter of the institution. In general, private institutions will be different from state institutions. Within state institutions, the role of the state tends to focus more on advocacy for upper-tier institutions, whereas lower-tier institutions are usually more tightly regulated in order to improve access to less-privileged populations.

Table 11.3 provides examples of the different roles of the state. It is intended to be illustrative rather than comprehensive. The state's role may be more complex than shown below. For example, the state may play a regulatory role in some aspects of governance, e.g., tuition, while playing a steering role in others, such as faculty salaries.

In mature environments such as in many developed countries, it is found that the quality of students graduating from an institution (though not necessarily from the educational system as a whole) will be lower if: (1) state policy favors student accessibility (equity) over merit, (2) state policy favors teaching over research, (3) governance structures focus more on managing tuition costs than admission standards, (4) governance structures focus more on managing salaries than faculty selection criteria, (5) administrative structures are more bureaucratic, and (6) administrative structures exclude nonstate stakeholders such as faculty and alumni (McDaniel 1996; World Bank 2000).

We hypothesize that the impact of a higher role of the state might be different in some respects in India. This is because the system dramatically changed in respect of the share of private provision, as noted above. Most of the new providers are raw and in the private sector. In some other respects, the role of the state should be similar to more mature environments.

One area of difference could be in the state's role in faculty selection. A common criticism of the newer private institutions in India is that they employ faculty of poor quality. For example, M. Anandakrishnan, Chair of the state-owned Madras Institute of Development Studies, a division of the National Institute of Social Science Research, argued that the quality of faculty in private institutions is below that of public institutions. He argues that this is because "They (the self-financing private institutions) generally treat the faculty somewhat like bonded labor in matters of salary and service conditions (Nuepa 2006:43)."

Similarly, the private institutions can waive their admission norms in favor of those willing to pay more.

Table 11.3 Differing roles of the state in higher education

Type	Policy	Governance	Administration	Role of state	Examples from US and India
2-year state-run programs	Equitable access	Controlled tuition, salaries, and class sizes (TSC)	Bureaucratic, i.e., rules based, set by the state	Regulatory	Foothill Community College, CA; Government Polytechnic, Pune
Second-tier state university	Higher teaching standards	Less controlled TSC; higher student and faculty standards (SF)	Less bureaucratic; some faculty influence	Steering	CA State University; National Institutes of Technology, India
First-tier state university	Higher teaching standards and research	Less controlled TSC; higher SF; freedom to pursue research	Less bureaucratic; in India, faculty also exercise influence. In the US, faculty, alumni, and donors exercise influence	Advocatory	University of CA system; IITs
Second-tier private university	High teaching standards	Flexible TSC. In India, reservations and state-subsidized or cross-subsidized fees for underprivileged students are common	In India, trustees primarily run the administration. In the US, faculty, alumni, and donors exercise influence	Advocatory	Menlo College, CA; P.E.S. Institute of Technology, Bangalore
First-tier private university	Higher teaching standards and research	Flexible TSC; freedom to pursue research	As for second-tier private university	Advocatory	Stanford University; BITS, Pilani

Note: Terms such as "higher" and "less" in the table above are used with reference to the type in the previous row

The private institutions get away with such behavior because of poor regulation and the newness of private provision. As a result, it is argued, students cannot easily distinguish good from bad private institutions (World Bank 2000). On the other hand, the state-owned institutions, which are more rules based, ensure that faculty selection and salaries and admission criteria meet minimum standards, even if sub-optimal (see also Box 1 for a discussion of this with regard to the IITs).

Hence, in an immature environment like India, we would expect that a responsible state will play a role that is more intrusive than in a more mature environment. For instance, if there is an excess demand for software engineering courses and if students are unable to distinguish good from bad institutions, the state may lay down minimum standards for faculty selection in new institutions (both private and public), such as possession of a graduate degree in engineering.

By contrast, other aspects of newness or immaturity of the system would not lead to differences between India and more mature environments. For instance, we would expect that high state involvement in determining which research projects to undertake would reduce quality even in a new institution. Shared governance between the state and other stakeholders such as faculty should also always be a positive contributor to quality.

Note that, sometimes, an immature state might be an obstacle to institutional maturation. Although the overall environment for software engineering education is immature, several mature institutions exist. For them, the state ought to institute different standards. In practice, a common complaint of the Indian higher educational system is that the state is intrusive even when it is not needed. One of the goals of this chapter is to identify areas where the state has not been responsive to the evolving institutional environment.

One of the differences between private institutions in India and a mature environment, such as the United States, is the role of trustees in administration, as indicated in Table 11.3. In India, our findings (see Sect. 11.5) indicate that private institutions are controlled either by the state or by trustees, depending upon the feature (standards, administration, etc.). Faculty play a limited role in India. In other words, although these are private institutions, the administrative structures are largely politicized, i.e., run by policymakers, and faculty and alumni are excluded from administration. We expect that, as with the state's impact, the exclusion of faculty and alumni ought to adversely affect quality.

We now turn to our detailed hypotheses, methodology, and data.

11.6 Empirical Tests

11.6.1 Methodology and Data

11.6.1.1 Methodology

The variables that are most reliably observed are administrative variables, such as the rules for setting tuition or eligibility requirements. Governance structures and the underlying policies can be inferred from these, although we also use qualitative questions, e.g., asking whether the institution focuses on cost management rather than faculty quality, in order to make more direct, if less reliable, assessments on governance structures and policy.

The hypothesis we study is:

$$\text{H1}: y = c + b_1 x_1 + \ldots + b_{11} x_{11} + e$$

Where y = quality of education.

x_1 = role of the state in influencing entrance requirements.
x_2 = role of the state in influencing teaching.
x_3 = role of the state in influencing research.
x_4 = role of the state in influencing faculty selection.
x_5 = quality of curriculum.
x_6 = politicization of the administration.
x_7 = quality of faculty who apply for jobs.
x_8 = quality of student intake.
x_9 = quality of infrastructure.
x_{10} = quality of research.
x_{11} = quality of university–industry interaction.
e = residual term.

The variable x_1, the role of the state in influencing entrance requirements, is measured by its role in setting fees, eligibility requirements, the number of students to be admitted, and selection of students. In each case, respondents were asked to rank the role of the state from 1 to 5, where 1 was the least centralized and 5 the most centralized. The average of these rankings for the four categories was taken as the measure of x_1.

Given India's institutional immaturity, we expect that the state will play an important role in influencing entrance requirements in most institutions. Within the immature environment, we expect that the mature state will offer greater freedom to more mature, higher quality institutions. Hence, we expect that the mean value for x_1 will exceed 3, while the sign of the regression coefficient will be positive. The predicted regression coefficients for this and subsequent variables are shown in Table 11.4.

The variable x_2, the role of the state in influencing teaching, is measured by its role in starting a new discipline, starting a new disciplinary specialization, determining the course syllabus, selecting textbooks, and assessing the quality of teaching. Respondents were asked to rank the role of the state from 1 to 5, where 1 is very low and 5 is very high. The average of these rankings for the five categories was taken as the measure of x_2. The expected value and sign are similar to x_1.

The variable x_3, the role of the state in influencing research, is measured by its role in determining research projects, on university–industry interaction and revenue sharing between faculty and department for outside work, such as consultancy projects. Respondents were asked to rank the role of the state from 1 to 5, where 1 is very low and 5 is very high. The average of these rankings for the three categories

Table 11.4 Expected range of values and sign of the independent variables

Independent variables	Predicted mean	Predicted coefficient sign
Entrance (x_1)	>3	+
Teaching (x_2)	<3	+
Research (x_3)	<3	0
Faculty (x_4)	>3	+
Curriculum (x_5)	>3	+
Politicization (x_6)	<3	–
Faculty intake (x_7)	>3	+
Student intake (x_8)	NA	+
Infrastructure (x_9)	>3	+
Research (x_{10})	>3	+
University–industry interaction (x_{11})	>3	+

was taken as the measure of x_3. As discussed above, the state should play a hands-off role in research, regardless of the maturity of the system. Hence, we expect that the mean value will be less than 3 and that the role of the state will not vary with institutional rank, i.e., the predicted sign of the coefficient is 0.

The variable x_4, the role of the state in selecting faculty, is measured by its role in determining the categories of faculty, the required qualifications of faculty, and faculty salaries. Respondents were asked to rank the role of the state from 1 to 5, where 1 is very low and 5 is very high. The average of these rankings for the three categories was taken as the measure of x_4. The expected value and sign are similar to x_1.

A set of independent variables was used as control variables. These were the quality of the curriculum, the quality of student intake, the quality of faculty, the quality of physical infrastructure (libraries, electronic media, bandwidth, etc.), the quality of research, interaction between academia and industry, and the politicization of the administration. Of these seven variables, the first six were ranked from 1 to 5, where 1 measured the best quality and 5 the lowest quality. In all six cases, we expect that higher ranked institutions will be of higher quality, i.e., the coefficient sign should be positive.

The mean values are likely to be less uniform. Curricula are likely to be less demanding in a weaker institution; given the newness of most providers, we expect that the mean value will be greater than 3. A similar argument applies to the quality of faculty, quality of physical infrastructure, quality of research, and the quality of university–industry interaction. However, the quality of students depends on many other factors, including the options available in other fields and the quality of the secondary and the primary education system.

The seventh independent variable, politicization, was ranked from 1 to 5, where 1 measured high politicization and 5 low politicization. Note that politicization refers to the intrusion of policymakers into the day-to-day functioning of the institution. This can happen in both state-owned and private institutions. We expect politicization to be high on average (mean value <3) and to be worse for lower-ranked institutions (negative sign).

The table below summarizes the conditions for predicted values and signs of the coefficients on the independent variable, as discussed above.

11.6.1.2 Data

The data set comes from a questionnaire that was administered face to face to 19 institutions. In each institution, either the head of the institution or the head of the computer science (or equivalent) department responded. Most of these institutions are in or near Bangalore (12), with four in Chennai and three in Hyderabad. The institutions were chosen randomly after stratifying the population into private colleges, state-run colleges, and centrally run colleges.

Three institutions that recruit software engineers, the Indian Institute of Management, Bangalore (for graduate management studies), Wipro, and Google were asked to rank the 19 institutions relative to best global standards. The institutions were ranked from 1 to 5, where 1 is the highest rank, 3 the middle rank, and 5 is the lowest rank. These ranks were averaged to obtain the dependent variable.

Other sets of data were collected by administering the same questionnaire nationally to a number of institutions. We also interviewed three American institutions using the same questionnaire and also to assess the quality of Indian undergraduates who apply to graduate programs in the United States. This set of data was used to corroborate the findings of the Bangalore-focused survey and is not part of the sample regression analysis below. The full list of institutions is provided in Appendix 2. Finally, we also report in the concluding discussion a survey of the time spent by Indian students inside and outside the classroom. This is used to corroborate some of the conclusions of the main data set and is not part of the sample regression analysis.

11.7 Findings

The average rank of the institutions sampled is provided in the table below.

The table below provides information on the average ranks of each tier.

The sample shows that the institutions surveyed produce a somewhat better than average quality of students, with a rank of 2.5. The gap between first- and second-tier state institutions is higher than between first- and second-tier private institutions. This confirms our discussion in the introduction wherein we noted that focusing on the upper-tier institutions had led the state to neglect the second tier.

A comparison of the actual means with the predicted means indicates the following:

1. The role of the state (x_1–x_4) is generally high. The exception is the research function. These values confirm our hypothesis that the state plays an important corrective role where it can, given the immaturity of the system, while it does not

Table 11.5 Sample rank of institutional quality

Type	First-tier state	Second-tier state	First-tier private	Second-tier private	Average state	Average private	All
Number	4	3	3	9	7	12	19
Average rank	1.4	2.9	2	2.9	2.1	2.7	2.5

Note: 1 is highest rank and 5 is lowest rank
Note: First-tier institutions were those ranked 2 or higher

intervene in functions which it cannot influence, such as research. In addition, the state plays a more intrusive role in setting teaching standards for private institutions than for state institutions. The former are the newer, more immature institutions; so this role appears to be appropriate.

2. The mean values of the independent variables are consistent with the hypothesis of mature state intervention in the context of an immature environment, particularly due to private provision. The quality of curricula, faculty, students, infrastructure, and university–industry interaction are higher than expected, suggesting that the quality of the system is better than would be expected. This may be an outcome of appropriate governance within the institution (despite active state involvement) or it might indicate that the state is playing an appropriate role. The high mean value of politicization suggests that the system is less politicized than expected. However, this is due largely to the low politicization in state-owned institutions, whereas politicization in the private institutions is higher, as the next two columns (of Table 11.5) show. This confirms the hypothesis that the private institutions' policymakers interfere more in the day-to-day functioning of their institutions relative to the state, which plays a more appropriate, hands-off role in state-owned institutions.
3. The unexpectedly high quality of the independent variables even among the private institutions (which are newer and less mature) suggests that quality for the system as a whole will improve further as the system matures. Meanwhile, the state-owned institutions currently offer a higher quality of education.
4. The low quality of research, despite limited state interference, suggests that other factors might be at work, such as private incentives. In our interviews, we found that the research function at even the highest ranked institutions is generally neglected. This is despite relatively generous allowances for research. Even in the smaller state-run institutions, it was found that faculty can relatively simply obtain funds for domestic travel, materials, and assistance. In some of the larger state schools, even international travel for conferences is funded. The might improve if the state instituted rules that required, for instance, that a certain proportion of research funding needs to come from industry or if rules of tenure included a research evaluation (this factor is mostly missing even in the highly ranked institutions). As the table above shows, the private sector ranks even more poorly than the state institutions on research, as may be expected given our discussion above.

We now turn to the sign of the coefficients:

Linear regression Number of observations = 19
$F(11, 7) = 5.99$
Probability > $F = 0.0128$
$R^2 = 0.7710$
Root MSE = 0.6001

Due in part to the small sample size, the regression coefficients are largely not significant. The only significant independent variable is the state's influence on entrance. A higher influence is associated with lower ranked institutions. In the context of the system's overall immaturity and overall high quality, we interpret this to mean that the state is playing a needed role, as discussed earlier.

11.8 Concluding Discussion

As with any system undergoing rapid change, the rate of change makes it difficult to rate the quality of engineering graduates. It is common for software firms in India to express fears about the quality of manpower relative to costs. This is attributed by them to the high demand for IT engineers relative to the supply. However, the data show that, at least for the near term, adequate supply exists. For example, in 2006, the number of new engineering graduates, MCAs, and engineering diploma holders was expected to be 495,000 (NASSCOM 2007:92). This should have met the software exporting industry's need for an additional 200,000 employees in 2006, a figure that grew at about 20% per annum. In the first 7 months of 2009 alone, the Indian regulator, AICTE, reported that 524 new colleges with a 4-year enrollment

Table 11.6 Sample ranks of independent variables

Independent variable	Mean	Predicted mean	Mean for state institutions	Mean for private institutions	Rank of differences*
Entrance (x_1)	3.7	>3	3.9	3.5	8
Teaching (x_2)	2.9	<3	1.8	3.6	1
Research (x_3)	1.8	<3	2.1	1.7	10
Faculty (x_4)	4.2	>3	4.3	4.1	7
Curriculum (x_5)	1.5	>3	1.1	1.8	3
Politicization (x_6)	3.6	<3	4.6	3.0	11
Faculty intake (x_7)	2.2	>3	1.9	2.4	4
Student intake (x_8)	1.9	NA	1.4	2.2	2
Infrastructure (x_9)	2.1	>3	2.3	1.9	9
Research (x_{10})	3.5	>3	3.1	3.7	5
University–industry interaction (x_{11})	2.5	>3	2.3	2.6	6

*Rank of differences is measured by ranking the ratio of the mean for state institutions to the mean for private institutions

Source: Survey Questionnaire

Table 11.7 Table of coefficients

Independent variables	Coefficient	Predicted coefficient sign
Entrance (x_1)	0.44*	+
Teaching (x_2)	0.07	+
Research (x_3)	–0.32	0
Faculty (x_4)	–0.21	+
Curriculum (x_5)	0.36	+
Politicization (x_6)	–0.07	–
Faculty intake (x_7)	–0.19	+
Student intake (x_8)	–0.04	+
Infrastructure (x_9)	–0.18	+
Research (x_{10})	0.28	+
University–industry interaction (x_{11})	0.11	+

*Significance at 5%
Source: Survey Questionnaire

Table 11.8 Correlation matrix

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
x_1	1										
x_2	0.45	1									
x_3	0.58	0.26	1								
x_4	0.82	0.54	0.54	1							
x_5	–0.16	0.24	–0.2	0.11	1						
x_6	0.02	–0.57	0.14	–0.14	0.47	1					
x_7	0.43	0.22	–0.01	0.26	0.14	–0.33	1				
x_8	0.05	0.23	–0.16	–0.02	0.26	–0.31	0.52	1			
x_9	0.29	0.11	–0.06	0.17	–0.06	–0.31	0.55	0.21	1		
x_{10}	0.2	0.34	–0.17	0.36	0.32	–0.4	0.18	0.39	0.38	1	
x_{11}	0.2	0.1	–0.13	0.05	–0.07	–0.19	0.6	0.52	0.6	0.52	1

capacity of 1,000 each on average opened. This remarkable rate of over two new colleges opening per day suggests capacity is adequate (www.aicte.ernet.in, downloaded August 9, 2009).

The difference in growth rates helps to explain why a perception of falling quality of recruits persists despite a rising average quality of graduates. Even though the average quality of the graduates is rising, the average quality of recruits at the firm level can fall. Whereas in earlier times, only the best engineers found jobs in the export sector, more recently, even poorer quality engineers find jobs.

It is important to note that the quality of *work done* may be higher even if the quality of the recruit is lower. This is because many of the leading IT firms in India provide their own training to supplement a university education. These include the leading Indian software service firms. Others work directly with educational institutions, providing curriculum and teaching kits. For example, Texas Instruments collaborates with 400 such institutions in India.[6]

[6] Source: Dossani interview with Dr. B. Mitra, CEO, Texas Instruments India, November 2007.

In this chapter, our intent was to provide a framework for analyzing the Indian higher education system's readiness for a new product and services economy. We argued that several conventional arguments about the advantages of the Indian education system such as knowledge of the English language, technical excellence, and scale of supply needed to be reassessed in the light of changes in the type of engineer needed and the changes within the Indian education system. The former set of changes required a consideration of the creative and managerial competences of engineers, while the latter was needed because of the dramatic change in the role of private provision.

For purposes of this introductory analysis, we considered only one discipline, software engineering, and limited our scope to an assessment of technical education. We first showed that India's greatest success was in establishing certain elite institutions, such as the IITs. The elite institutions like the IITs are managed and funded under a different organizational model than the overwhelming majority of state-owned institutions. They are run by the federal government with levels of funding that would be unaffordable were these to be generally applicable to all state-owned institutions. This means that, under the present environment, the "IIT-model" is not widely replicable within the country.

Nevertheless, elite institutions like the IITs offer some important lessons. The first is that the policy goal of achieving excellence for a small cohort of students chosen entirely on a rules-based criterion of merit and funded primarily by the state can achieve the strategic target of attracting the country's best students and faculty into a small number of institutions. This sets the conditions for a rapid establishment of high quality. Certain minimal other conditions need to be fulfilled, such as a hands-off approach by the state to the educational core of faculty selection, curriculum development, and minimal infrastructure. But, beyond this, even an intrusive state that otherwise runs a bureaucratic, even a corrupt administration, can co-exist with a high-quality education.

Nevertheless, the elite institutions are under threat. The primary threat is to faculty retention. The state caps salaries at its institutions (as of 2009, to Rs. 80,000 per month, or about $1600), at levels significantly below what private institutions can afford. The recent proliferation of private provision with higher budgets allowed them to poach the best faculty and has already led to considerable erosion in faculty quality across the board from leading to smaller state-owned institutions country-wide. The state has tried to be responsive, offering better infrastructure and research budgets, but it remains insufficient when the private providers can offer salaries that are several times what faculty in the state-owned institutions currently earn.

The overwhelming majority of state-owned provision is by individual states. This is an outcome of India's constitution where the central (federal) government assumes responsibility for setting standards, while the state governments take responsibility for funding and provision.

The institutions run by the individual states are generally of significantly lower quality than federally run institutions. This is largely an outcome of funding and results in a serious quality gap. In software engineering, for instance, there are about a dozen institutions, mostly federally run, that offer a high (first tier)-quality education, then a large gap, followed by lower-tier (third-tier) state-run institutions. The absence of a quality continuum at the second tier disadvantages students who fail to enter the elite institutions and must settle for a third-tier institution.

The state began to recognize this problem in the mid-1990s and responded with encouraging private provision. The private providers, in turn, responded energetically. Although they are required to be legally organized as nonprofit societies and trusts, private provision offers enough opportunities, given the immature environment, for personal gain. In engineering, over three-fourths of the providers are now private, a dramatic turnaround from 1995, when their presence was negligible.

The private providers are key to the system's future. Although they currently occupy the lowest tiers of quality, over time, as they mature, they, more than state-owned providers, are going to provide the scale, depth, and scope of the system. Already, our analysis showed that some private providers are maturing into high-quality providers.

Nevertheless, the state remains a critical player. Its institutions set the current benchmarks for standards, of course (as well as providing fertile ground for recruiting faculty!). But its primary influence is through its role as the system's regulator. The system allows it to be as intrusive as it wants. This is because the law allows the state to set standards for institution-specific admissions; standards for faculty recruitment; and funding standards for research; and to shut down those institutions that fail to meet these standards.

Hence, a complex environment characterizes the higher education sector. The state as regulator, provider, and financier must interact increasingly with the private sector as provider. What sort of outcomes resulted? Do they meet the needs of the nation?

To assess this, we surveyed institutions that are important suppliers of software engineers to India's software capital, Bangalore. We considered the role of the state through the assessment of its influence on fundamental aspects of an institution, such as entrance requirements, teaching, research, and faculty selection. The influence was evaluated through three layers: influence on institutional policy (such as the focus on teaching versus research, equity versus merit, etc.), influence on governance structures (such as the rules for selecting or compensating faculty), and influence on the administrative structures (how flexible are the rules for admission? Do policymakers influence admissions directly and waive standards in return for higher fees?). These influences and quality outcomes such as the quality of research and the quality of curriculum were evaluated against the quality of the institutions as ranked by recruiters, both commercial and academic.

We found that the average quality of the institutions that supply Bangalore with software graduates is high and that the public sector is of better quality than private institutions. The state-owned institutions are superior in certain key variables: curriculum, students, and faculty. Nevertheless, even the private providers score well in these respects and score better than the state-owned providers on infrastructure. At the operating level, the state-owned providers tend to be less influenced by policymakers. By contrast, the private providers are more politicized. In one key respect, research, the weakness of quality, cuts across all types of institutions.

The finding that private institutions are driven by policymakers (usually trustees of the institution) rather than faculty, alumni, and other stakeholders suggests that this ought to adversely affect quality. As noted earlier, faculty-driven institutions tend to drive quality higher than politicized administrations. In a follow-up study by one of the authors, the impact of high politicization is being studied. One of its impacts is on the way students spend their time in the classroom. We find that Indian institutions tend to focus on rote learning, lecture-driven education rather than learning through small group projects and self-study. This is shown in Table 11.2 above, where we provide a comparison with a leading U.S. institution, Stanford University.

From the table, it appears that students spend somewhat more time in India studying the major subject than at Stanford University. However, substantially less time is spent on other subjects. Second, three times as many hours are spent in the classroom and closed laboratory work as on self-study in India, a reversal of the situation at Stanford University. Third, classroom hours in India are dominated by lectures whereas small-group work predominates in Stanford University.

It is possible that the lecture-dominated style prevalent in India is the result of a long tradition of politicization and lack of faculty incentive to adopt modern methods of teaching, leading to less-rounded student development.

However, the unexpectedly high quality of the independent variables even among the private institutions (which are newer and less mature) suggests that quality for the system as a whole will improve further as the system matures.

Our second key finding is that the influence of the state is generally high on teaching, entrance, and faculty selection. The exception is the research function, where the state plays a hands-off role. These findings confirm our hypothesis that the state plays an important corrective role where it can, given the immaturity of the system, while not intervening in functions which it cannot influence, such as research. In addition, the state plays a more intrusive role in setting teaching standards for private institutions than for state institutions. The former are the newer, more immature institutions; so this role appears to be appropriate.

The low quality of research, despite limited state interference, suggests that other factors might be at work, such as private incentives. In our interviews, we found that the research function at even the highest ranked institutions is generally neglected. This seems to reflect poor university–industry linkages for research, even though they appear to be satisfactory from a recruiter's viewpoint. Even the final-year design project of the student is typically done within the university rather than at a commercial enterprise.

This weakness in research is despite relatively generous allowances for research. Even in he smaller state-run institutions, it was found that faculty can relatively simply obtain funds for domestic travel, materials, and assistance. In some of the larger state schools, even international travel for conferences is funded. The quality of research might improve if the state instituted rules requiring, for instance, that a certain proportion of research funding needs to come from industry or if rules of tenure included a research evaluation (this factor is mostly missing even in the highly-ranked institutions). The private sector ranks even more poorly than the state institutions on research.

In summary, the education environment we studied shows that the institutional structure can produce a quality of engineer that is suited for the present needs of the workplace. Interestingly, all institutions, from the lowest to the highest ranked, seem to aim to produce technically competent engineers rather than target their output within a creativity-driven quality continuum.

As the demands of the marketplace evolve, certain weaknesses, particularly in the research and project management functions, will need to be addressed. We argued that the role of the state will be critical. So far, the state has demonstrated its capability of being an effective regulator. To address evolving demands, new capabilities will no doubt be needed by the state. In particular, the state needs to address the issue of the quality gap at the second tier and the absence of research capabilities at the first tier. It also needs to increase autonomy to first-tier institutions, particularly in administrative structures. Toward private providers, the state currently plays a more intrusive role than it would in a more mature system. This reflects the immaturity of the private provision system, as evidenced by politicization and generally lower quality outcomes. The challenge the state's role raises is how the state ought to fashion its regulatory role so that it can transition to a less rules-based system as the environment matures. This is a transition that it has not achieved even in the best state-owned institutions and remains, therefore, a challenge.

How replicable is India's apparent success with its higher education system? Here we offer a caution. The higher education system that resulted in India was not foreseen and caught the nation's education planners by surprise. No one expected that the private sector would respond as it did. Planners designed the system to allow only nonprofit private providers. Planners expected that those private providers that would enter the system would be philanthropic. They would exist at the margins of the then larger state system. Accordingly, planners encouraged them, through incentives, to set up their institutions in smaller towns.

Instead, the private providers stormed into the big cities first, preferring to ignore the incentives, and only later, after 2007, spread to smaller towns. Many made profits illegally (by charging an upfront fee, the capitation fee).

A key factor was rising federalism: strong states like Karnataka and Tamil Nadu were able to provide the regulatory support that made private sector entry possible. The second key factor was the IT industry's willingness to be the market maker. In this, the role of the large Indian IT firms was critical. The large Indian IT firms rigorously rank the engineering colleges and enter into long-term partnerships with the better colleges, assuring them of preference in recruitment, internships for students, and joint research projects for faculty. These ranks are then used by entering students to choose colleges, creating a virtuous circle of rising quality due to the efforts of college to raise their ranking. It is unlikely that an industry characterized by a large number of small firms would have played the role of market maker.

So, India is unique in some ways. China offers an alternative, perhaps more replicable, model: an entirely state-run system in which tuition fees, which average $800 per annum, pay for 50% of costs. It, too, has grown rapidly: for example, five million students are, as of 2009, enrolled in undergraduate engineering programs. The share of the burden per student appears to be higher in India. In India, the state and "aided" private colleges (these are privately owned and managed, but accept state aid to pay for costs such as infrastructure and faculty salaries; in return, they must charge the same tuition fees as state-run institutions) account for 40% of total enrollment and charge fees that cover 30% of costs. The unaided schools, as noted earlier, recover full costs through tuitions (endowments are insignificant). Hence, the share of total national costs of education borne by students in the system is over

70%. This may be important for achieving long-term sustainability, although, in the short-term, it may adversely affect enrollment.

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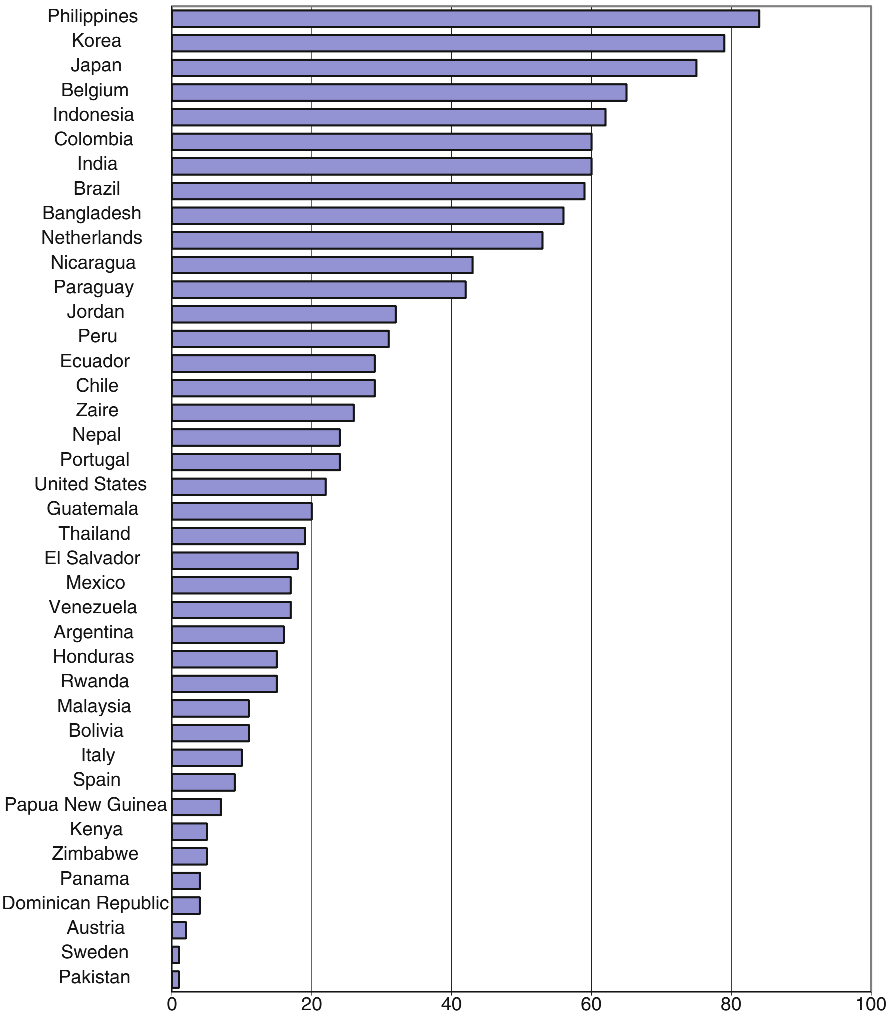
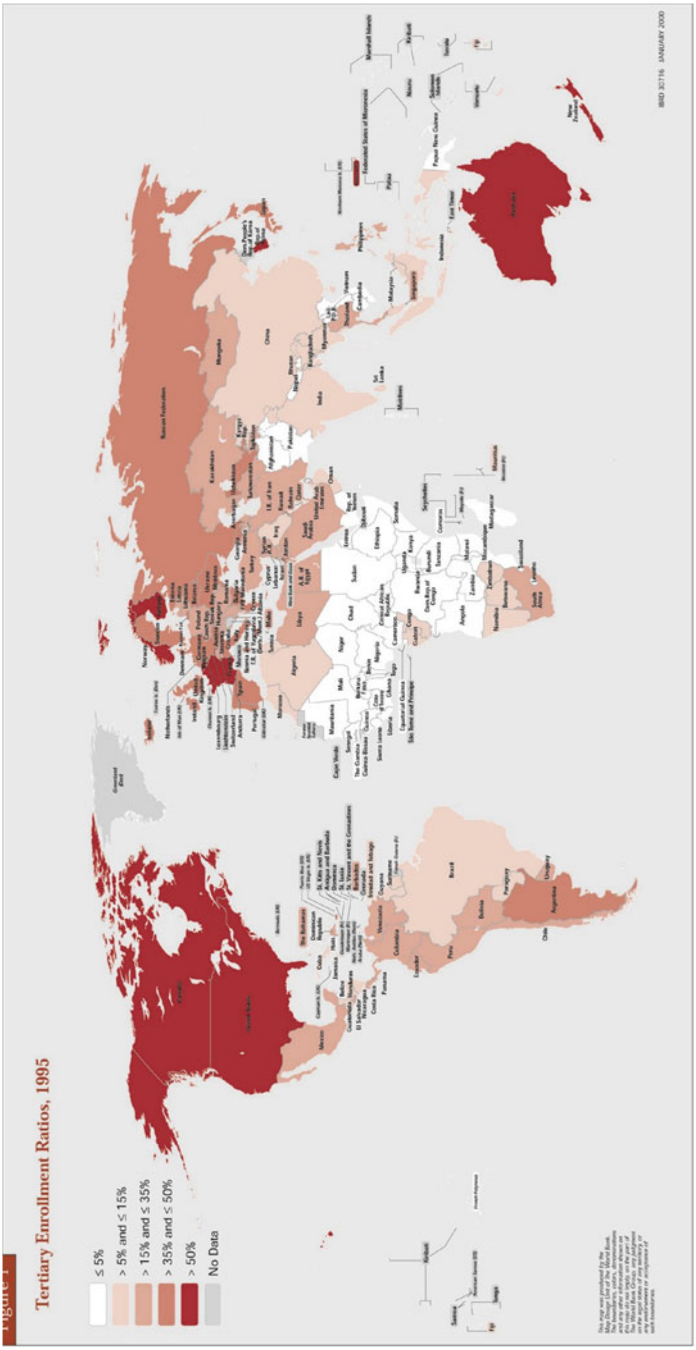
Appendix 1

Share of enrollment in private higher education and enrollment rates
Source: World Bank 2000:39





This map shows the variation in tertiary enrollment ratios across the countries of the world. In general, people in countries that are more developed economically are more likely to be enrolled in higher education. Nevertheless, there are also regional trends, and numerous countries have different enrollment ratios than might be expected on the basis of per-capita income.

Appendix 2

List of institutions in regression sample (in Bangalore, unless otherwise noted)
Acharya Polytechnic
Bellary Engineering College
BMS College of Engineering
College of Engineering, Guindy (Chennai)
Dayananda Sagar College of Engineering
Government Polytechnic for Women
IIT Madras (Chennai)
International Institute of Information Technology (Hyderabad)
Indian Institute of Science
Jawaharlal Nehru Technological University (Hyderabad)
JSS Academy of Technical Education
MSR Institute of Technology
Madras Institute of Technology (Chennai)
Nizam Institute of Engineering and Technology (Hyderabad)
P.E.S. Institute of Technology
SJ Government Polytechnic
SRM Institute of Science and Technology (Chennai)
VVS Polytechnic
Vijaynagar Engineering College

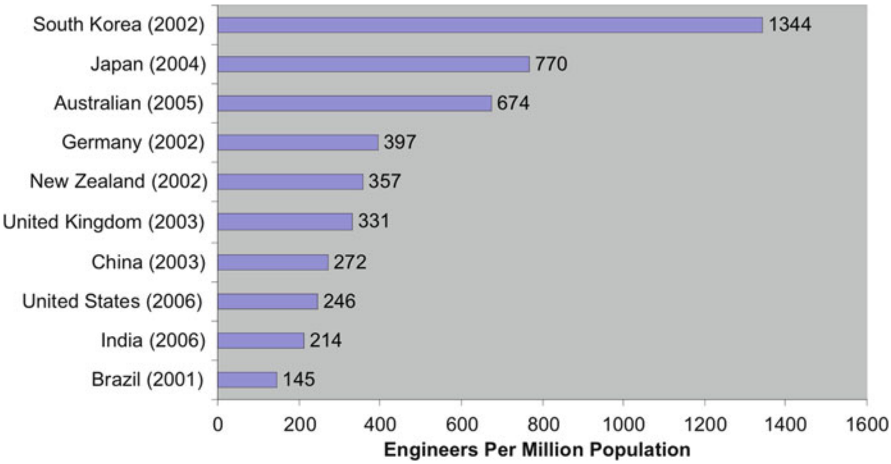
Other institutions interviewed (not used for sample tests)
India
- Allahabad University, Allahabad
- Banaras Hindu University, Varanasi
- Devi Ahilyabai University, Indore
- IIM, Calcutta
- IIT, Bombay
- JSS Mahavidyapeeth, Delhi

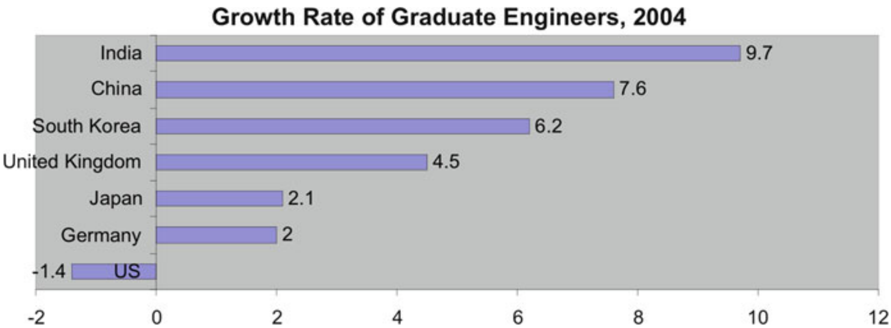
USA
- Illinois Institute of Technology, Champaign-Urbana, IL
- San Jose State University, San Jose, CA
- Stanford University, Stanford, CA

List of institutions for the Tamil Nadu students' survey reported in Table 11.4
College of Engineering, Guindy
Madras Institute of Technology
Sri Sai Ram Engineering College
PSG College of Technology
RMD Engineering College
RMK Engineering College
Sri Krishna College of Engineering
Vellore Institute of Technology

Appendix 3

Massification of higher education: number of engineers per million population and growth rates
Source: Banerjee and Muley (2007)





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Chapter 12
Bayh–Dole and Alternative University Technology Transfer Regimes

Martin Kenney and Donald Patton

12.1 Introduction[1]

One of the primary motivations in passing the Bayh–Dole Act (BD) of 1980 was the belief that government-owned patents were insufficiently utilized (Berman 2008; Eisenberg 1996). To remedy this shortcoming, Congress designed the BD Act so that federal contractors, including universities, could claim title to inventions made with federal funds. BD also standardized the procedures for vesting the control of federally funded research inventions with contractors (Mowery et al. 2004; Slaughter and Rhoades 2004).[2] The U.S. university invention ownership model has been heralded as the global best practice by many observers (e.g., *The Economist* 2005; OECD 2003).[3] More recently, though, some have begun to question this assessment (Nelson 2004; Washburn 2005, and in particular, Litan et al. 2007). While BD was supported at the time of its passage as a means to facilitate the transfer of federally funded inventions, it has in fact turned out to be a profound technology policy decision. With BD came a new university invention commercialization model, which university administrators believed would be a source of income. For those interested in the university's role as an innovator in the economy, it is necessary to have an understanding of the university invention ownership model and its contradictions (for reviews, see Rothaermel et al. 2007; Shane 2004).

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[1] For a more lengthy discussion of the concepts in this paper, see Kenney and Patton (2009).

[2] The Federal government retained a royalty-free, nonexclusive license.

[3] In particular, The Economist (2002) described Bayh-Dole as "Possibly the most inspired piece of legislation to be enacted in America over the past half-century… More than anything, this single policy measure helped to reverse America's precipitous slide into industrial irrelevance" (December 12, 2002). This quote is regularly cited by supporters of the Act.

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The significance of BD extends well beyond the United States. Accepted as best practice, it has been imitated internationally, despite little evidence that BD has been responsible for the successful diffusion of technology from U.S. universities to firms. Our analysis here suggests that BD is, in fact, an inefficient method for ensuring technology transfer and that other models, including inventor ownership, would be more effective. An examination of other nations that have had successful university technology diffusion also suggests that an open and critical discussion of various models could result in an improved technology diffusion regime (Geuna and Nesta 2006; Mowery and Sampat 2005).

The BD model is not the only model for organizing technology diffusion and commercialization. Litan et al. (2007), among a number of recommendations, suggested the first model we discuss, which vests invention ownership in the inventor. A second approach argues that the diffusion of university inventions would be improved by weakening property rights in these inventions. One way of doing this is to place university inventions in the public domain (Dasgupta and David 1994; Rhoten and Powell 2007). A less radical variant proposed by Nelson (2004) limits universities to offering nonexclusive licenses for inventions. In the remainder of this chapter, the BD university ownership model is examined, and each of these alternatives is discussed, though we concentrate on the inventor ownership model because it has been less discussed in the scholarly literature.

12.2 Background

One critical concern of Congress in passing the BD Act was a belief that the more effective commercialization of university inventions would sustain U.S. economic preeminence, which at the time was being challenged by Japanese export success (Berman 2008; Brooks 1993; Stevens 2004). The objective of BD was to encourage the transfer of technology, produced by federally funded research, to society by giving universities the right to commercialize these inventions without federal interference. In exchange for the property rights to the inventions came an affirmative obligation by the universities to market them actively, which led to the formation of university technology licensing offices (TLOs), though some universities already had TLO-like operations in place prior to 1980 (Eisenberg 1996; Mowery et al. 2004; Sampat 2006).

Patenting and licensing by universities increased significantly after 1980, and many observers have interpreted these trends as persuasive evidence that BD clearly met the objective of facilitating the transfer of federally funded university technology to the business sector. The share of university patenting to all U.S. patents filed increased from 0.3% in 1963 to just under 4% in 1999, yet the rate of increase in university propensity to patent dates back to the 1970s and does not indicate a structural break after 1980 (Mowery and Sampat 2005: 120). The general conclusion of those examining the data is that while BD certainly simplified the university technology transfer process, much of the growth of technology transfer as measured by university licensing and patenting would have occurred in the absence of the BD legislation (Mowery et al. 2001). Yet, the primacy of BD in achieving this increase in university technology transfer is still widely maintained in policy presentations (OECD 2000) and academic journals (Swamidass and Vulasa 2008).

Throughout the twentieth century and up until the early 1980s, there was debate about the desirability of commercializing university research, particularly in biology. However, this disdain for commercial motivations began to change as biology, the largest recipient of federal funding, underwent a technical and commercial revolution. First, molecular biology rose as a field of science which increased the likelihood that university research in this area would produce commercially valuable pharmaceuticals and biomedical techniques (Nelson 2004). Second, changes in intellectual property (IP) law, particularly the Diamond vs. Chakrabardy Supreme Court decision of 1980, established the validity of patenting of new organisms, molecules, and research techniques that were emerging from university research (Mowery et al. 2001: 103). The new techniques of molecular biology were found to produce new, and potentially extremely valuable pharmaceuticals that could be capitalized by researchers in small firms (for an extended treatment of this period, see Kenney 1986; also Jong 2006; Colyvas 2007). In many respects, BD was a formalization of an already existing movement toward commercialization (Berman 2008). It did, though, establish the social acceptability of university researchers to patent inventions and laid the foundation for new sources of income for many universities. The institutional vehicle to manage this new income potential was the TLO.

12.3 The University TLO: A Vehicle for Technology Transfer?

Managing technology licensing and relationships with industry is difficult for universities as they are not for-profit entities, and they cannot manage and exploit inventions in the same way as a private firm. For example, at universities the range and variety of potentially valuable inventions is far greater than is likely to emerge from the R&D lab of a private firm. Moreover, the importance of patents differs by industry (Levin et al. 1987), as suggested by the patent literature, and this demonstrates why university TLOs need different procedures, methods, and goals for differing industries. In fields such as software and electronics, the significance of patents in terms of facilitating technology transfer is dubious (Jaffe and Lerner 2004). As a general observation, patents make up only a small fraction of the knowledge transferred from university laboratories to industry. In most industries, the most important channels by which university research is transferred to industry is through publications and conferences, channels that characterize open science (Nelson 2004; Sampat 2006).

Critical case studies can provide insight into the significance of TLOs for technology transfer. One of the most studied and most lucrative set of university-owned patents ever issued, the Cohen–Boyer (C–B) patents, consisted of a process patent and three quite general composition of matter patents issued during the 1980s on a pioneering and fundamental technique for the creation of genetically engineered microorganisms (Hughes 2001; Kenney 1986: 258; Powell et al. 2007).[4] Over its 17-year life, C–B produced in excess of $255 million in revenues for Stanford University and the University of California.

While the C–B patents generated great revenues for Stanford and the University of California, there is no reason to think that patenting was necessary for this technology to be transferred to industry. Within months after being revealed at a 1973 Gordon Conference, university laboratories around the world began using the C–B process. Even if C–B had never been patented, the fact is that in the late 1970s a number of newly established firms were already practicing the C–B technique. The technique was being adopted, regardless of whether it had been patented or not.

A similarly important invention, developed during the same period, provides an additional example. Columbia University extended licenses of Richard Axel's co-transformation process to 34 firms, generating $790 million to Columbia over the patent period. As in the case of C–B, firms were using Axel's process shortly after it was described in the scientific literature but prior to Columbia being granted a patent to the process (So et al. 2008; Sampat 2006).

In both the case of the C–B technology and the Axel co-transformation process, universities patented inventions that would have been utilized by industry in the absence of such patents. There is little reason to believe that inventions such as these will remain unused due to a lack of proprietary protection through university patenting.

12.4 The Inventor–TLO Relationship

The basic relationship in the university ownership model consists of a researcher disclosing an invention to the TLO. In this transaction, there are two actors: the inventor and the university TLO. If the invention is licensed, there is a third actor – the licensee. One added complication is that the inventor may become the licensee.

One major justification for university ownership is that it administers and manages the IP for the university inventor, that is, it performs a service for the inventor. In cases in which the university negotiates with an outside firm, it might be argued that the TLO has an advantage in terms of institutional power and licensing experience. In such a case, the TLO can find licensees that the inventor could not find, or secure higher licensing fees. In this situation, both the inventor and the university benefit by the TLO's knowledge of the market.

Hellman (2007) uses this argument to advance an affirmative case for the TLO in commercialization. In Hellman's model, the assumption is that the TLO, acting on behalf of the university owning the patent, has superior knowledge on how the invention may be used and by which firms. The general result of this analysis is that

[4] According to Reimers and others, Hughes (2001), which is based on interviews with nearly all of the key actors, is the definitive history of the C–B patent.

the inventor profits by delegating the search for licensees to the TLO and that such a result is optimal. Of course, if the TLO is not more effective in this search than the inventor, then it is preferable that the inventor has the rights to the invention (Hellman 2007: 28).

Does the TLO, as Hellman (2007) argues, have search capabilities superior to the inventor? Perhaps, but it must be kept in mind that the inventor is steeped in the literature of the invention, knows current research competitors and whether they are working in public or private sector institutions, and has ideas about the invention and its possible applications. Thursby and Thursby (2004) confirm this in their observation of "the extreme importance of personal contacts between the firm's R&D staff and university personnel." Not only are the inventors likely to have the best knowledge of which firms might be interested in an invention, but they also play a vital role "in the transfer of technology after an invention is made."

Since the technology transfer process is characterized by incomplete information, TLOs and their personnel are often measured in terms of revenue generated by their operation. As a result, the emphasis of a TLO judged on this basis naturally shifts to maximizing revenue. Because nearly every university is based on annual budgets, the dominant strategy of such a TLO would be to favor upfront payments from deep-pocketed large firms and to pursue aggressively only those inventions that the technology licensing officers believed had the greatest potential payoff (Lemley 2007). However, universities could inadvertently limit university research spin-offs by concentrating only on inventions with clear payoffs. In a study of the commercialization of university-derived inventions in electron microscopy by small start-up firms, Cyrus Mody (2006: 80) concluded that "policy-makers cannot predict which [research] communities will generate profits, and will hinder all if they try to encourage only profitable ones at the expense of the rest."

In the quest to generate revenues, some TLOs may resort to behavior that may be considered unethical, such as patent troll-like strategies such as pursuing "submarine" patents (see, for example, Rai et al. 2009).[5] An excellent example of questionable behavior is Columbia University's secret efforts to extend the Axel transformation patents by asking for Patent Office continuations. They succeeded in getting the contested patent issued 2 years after the first group expired (*Harvard Journal of Law and Technology* 2004; Colaianni and Cook-Deegan 2009).[6] The primary goal of Columbia's TLO was not to transfer technology but to maximize revenue.

[5] A "submarine" patent is an informal term for a patent first published and granted long after the original application was filed. In such cases, one set of individuals may invest significant sums in developing a body of knowledge without being aware that there exists a firm that already has a patent on this knowledge. These patents violate one of the fundamental goals of the patent system, which is to make the knowledge public so that others can be aware of it. When the submarine patent finally emerges, other users may have made significant investments that are now hostage to the patent owner.

[6] The extent of this drive for more income was on display when Columbia University lobbied a U.S. senator to add an amendment to a completely unrelated bill in an effort to extend the Axel patents (*Harvard Journal of Law and Technology* 2004: 596).

Because the objective of a TLO in many cases is to monetize inventions rather transfer technologies, it will strive to negotiate a sale of rights to a commercial entity. The commercial entity, because it operates in specific business areas, almost invariably has a better understanding of the value of the invention than does the TLO. In addition, the commercial entity has the possibility of approaching the professor directly for a consulting relationship to organize a "gray" technology transfer (Link et al. 2007).

If the TLO is badly managed, or so small that it lacks sufficient personnel qualified in the specific technology underlying the disclosure, the result can be the frustration of technology transfer and the cumulative development of a negative reputation. TLOs that have a reputation of being incompetent or difficult to work with are either shunned or approached by potential licensees adversarially (Greenbaum and Scott 2010; Owen-Smith and Powell 2001; Silverman 2007). TLOs that develop adversarial relationships with faculty discourage further disclosures and encourage inventors to circumvent university regulation by transferring inventions to off-campus entities outside the official disclosure system.

Because the university owns the IP to all inventions emerging from its employees, the TLO is the centralized intermediary for technology licensing and has complete responsibility for commercialization. This responsibility rests with the TLO despite the fact that the inventor is often the best-informed actor regarding the science of the invention and, often, its possible applications and potentially interested licensees. This does not mean, however, that TLOs should have no role to play in the technology transfer process. Indeed, well-run TLOs are in a position to assist in this process on the basis of the services they offer to inventors.

12.5 Two Alternative Models to Bayh–Dole

We consider two alternative university IP models to the BD regime. The first model is based on the premise that inventor ownership will result in greater and faster technology commercialization. We argue that ownership be vested in the inventor, precisely because the inventor is the individual who best understands the invention and its potential and is most likely to have ideas for potential customers. The efficiency argument for inventor ownership cannot, though, answer the normative question of whether the university should be rewarded for being the institution within which the invention was developed.

The second model is based on weaker ownership rights and has two variants (Eisenberg 1996; Nelson 2004; Rhoten and Powell 2007). In the first variant, all university inventions would be placed in the public domain and available to all users. In this public domain variant, the university administration would be removed from direct involvement in the technology transfer process, and the university would return to its role as a platform for research and instruction. A second, less drastic, variant is mandatory nonexclusive licensing.

12.5.1 Inventor Ownership

The inventor ownership model decentralizes the invention dissemination decision by granting the IP of the invention to the actors closest to the knowledge creation process and therefore the ones most likely to have the best information regarding its commercialization. This model already exists as a default in cases in which universities decline to exploit the invention, and the inventor petitions the federal sponsor for the rights (Chew 1992).[7] If inventors owned the IP to an invention, then they could choose to use the university TLO or any other organization to commercialize the technology, including commercializing the technology themselves or placing the invention in the public domain. In an inventor–ownership model, the inventors would be the principals, and they could secure an agent.

Transferring property rights to the inventor raises normative questions regarding the propriety of allowing individuals to capture the entire benefit from inventions developed with public funds used to advance scientific knowledge. This issue could be addressed in a variety of ways. For example, university employment contracts could be written that provide to the university a set percentage of the equity or licensing proceeds of any invention university researchers make as a result of their work on campus. This tithe should be sufficiently small so as not to discourage inventor commercialization. This pre-arrangement would greatly reduce the burgeoning gray market that currently exists where inventors transfer inventions to off-campus entities outside the official disclosure system.

Inventor ownership need not lead to the demise of the university TLOs. Technology transfer and commercialization requires competence and skills across a wide range of activities, including technology assessment, patent search, marketing, patent law, and IP issues. This competence must be combined with an appreciation of the specific science and industry associated with each particular invention and then brought to bear in the process of negotiation with one or more firms, possibly including the inventor's start-up firm. Under an inventor ownership system, TLOs would benefit as they would be relieved of the pressure to manage inventions that have little prospect of success but for which they have a responsibility.

A university TLO's location on campus would be a strong advantage in attracting inventors. Many faculty inventors not wanting to expend the time and effort on commercializing their inventions, but also hoping that the invention would be successfully commercialized, would almost certainly turn first to their local TLO. This conjecture is based on experience. In 1969, when Niels Reimers established the Stanford TLO, he was faced with the challenge of convincing inventors of the utility of the TLO.[8] These starting conditions may explain why the Stanford TLO retains a

[7] It is possible for the inventor to petition the funding agency for the rights to an invention, but this is time consuming and costly.

[8] See Nelson (2005) concerning Reimers' first successful patent and licensing of software for musical synthesizers.

strong service orientation (Ku 2008; Owen-Smith 2005). Altering ownership rights would require TLOs to operate as service organizations and to shift the relationship from one structured to serve the university to one structured to serve the inventor–owner.

In most university settings, the TLO will be in the best position to provide these services, and this fact will be appreciated by most university inventors. It is in those cases where there is a significant difference of opinion between the TLO and the inventor regarding the process of commercialization, or where the TLO is not capable of providing these services, that real difficulties occur.

Consider the possible situations that can arise. Suppose in one case that an inventor mistakenly believes that their invention is of commercial value, or that the TLO is pursuing the wrong path to commercialization. If the inventor, as the owner of the IP, acts on these mistaken beliefs, this will become apparent over time. The cost of an approach that allows inventors to make mistakes is that some inventions will fail to be commercialized in a timely fashion. The benefit would be that an effective TLO would be vindicated, and this would be observed by the university community. Over time, the true value of the TLO would be accurately determined. By decentralizing the decision making to each inventor, errors in judgment are also decentralized. Suppose in the second case that the TLO is not capable of adequately understanding and marketing the innovation, if the university holds the IP, then the TLO controls all of the inventions, and the inventor must follow the path to commercialization set by the TLO. Unlike the inventor ownership case where decentralized decision making allows for multiple paths to commercialization, the current BD system prohibits such experiments in alternative paths. Note also, that by allowing inventors to follow their own path to commercialization, many of the most unpleasant disagreements between university inventors and TLOs could be avoided.[9]

In most instances, both the inventor and the TLO will appreciate each other's competence in different aspects of the commercialization process. The inventor is the most informed actor on the science and often on the applications of the invention, while the TLO will have the greatest experience in negotiating a license to commercialize the invention. In those cases where these beliefs are jointly held by the TLO and the inventor, the same basic path to commercialization will be followed whether the inventor or the TLO holds the IP to the invention. In those cases, though, where there is significant disagreement as to the best means to commercialize the invention, we argue that it is better that the IP is held by the inventor.

[9] See Silverman's (2007) January article in *The Scientist* for an insightful discussion of these disagreements from a practitioners' point of view. See also the IP Advocate (www.ipadvocate.org), a website dedicated to university technology transfer issues from an inventor's point of view, where numerous cases of serious legal disagreements between university inventors and their TLOs are examined in some detail.

12.5.2 Experiences with the Inventor Ownership Model

Because the inventor ownership model currently does not exist in the United States, no current direct domestic comparisons can be made. Stanford University was the source of many valuable university start-ups both before and after BD's passage, but prior to the university's 1994 policy mandating disclosure of all inventions to the TLO. Even more to the point, the University of Cambridge in the UK is a useful comparison because up until a new mandatory university ownership scheme was implemented beginning in 2001, researchers owned their inventions. Though not discussed here, the University of Waterloo has the strongest policy of inventor ownership in Canada and is widely recognized as having the greatest number and most valuable spin-offs of any Canadian university (Bramwell and Wolfe 2008).[10] The final comparative case is Europe, which has a variety of different models and where technology transfer, until recently, occurred almost entirely outside official university channels.

Stanford has a long history of entrepreneurial technology transfer (Lowen 1997). In an archival study of the evolution of the Stanford Office of Technology Licensing procedures, Colyvas (2007: 468) shows in the biomedical field that initially there were four quite different models for organizing the relationship between university laboratories and firms. For Stanford, as Colyvas and Powell (2007) show, commercialization activity in biology grew most rapidly in the 1990s.[11]

While the Stanford TLO was not central in commercializing digital technologies, the most visible technology transfers occurred in this field in the 1980s prior to the 1994 university policy of mandating disclosure. In 1982, Sun Microsystems, a firm commercializing networked workstations, resulted from an entrepreneurial collaboration between three Stanford graduate students and a UC Berkeley graduate student. In 1984, Cisco Systems was formed by two Stanford staff members who built routers to link the then separate Stanford local area networks. In 1982, Silicon Graphics commercialized a software program, the Geometry Engine that Professor James Clark and graduate students had developed at Stanford. Though in each of these cases the Stanford TLO was involved, its actions were not critical to commercial success. At Stanford, then, there is evidence in the United States for successful university technology commercialization without the involvement of a TLO. There is also little evidence that technology transfer increased since the 1994 decision to require that all inventions developed at Stanford be disclosed to the TLO.

Until recent policy changes, the clearest case of a global-class research university practicing inventor ownership was the University of Cambridge. Although no international comparisons have been made, it is quite possible that Cambridge is the most fertile university in terms of technology-based entrepreneurship outside the United States (Garnsey and Heffernan 2005; Druilhe and Garnsey 2004; Myint et al. 2005;

[10] The University of Waterloo spinoff that has been the greatest success is Research in Motion, which was founded by two graduate students.

[11] Despite the critical importance of Stanford's TLO as a model, the most important early Bay Area biotechnology firms were spin-offs of the University of California, San Francisco (Jong 2006: 252).

Segal Quince Wicksteed Ltd. 1985).[12] Garnsey and Heffernan (2005: 1129) describe the situation at Cambridge as being laissez-faire with respect to university involvement in technology transfer as no active support was provided. In 2001, the university's unusual policy of granting IP to its staff was changed, and the University of Cambridge conformed to new UK government rules implementing a BD-like university ownership model.

While it is too early to determine of the effect of this change in IP ownership at Cambridge, Breznitz (2008) found that from 2001, the year the university took ownership, to 2004, the number of biotechnology spin-offs decreased even while the UK and global population of biotechnology firms increased. Her results suggest that university ownership of IP may be impeding technology diffusion, at least in terms of researcher entrepreneurship, the mechanism that made Cambridge the most successful entrepreneurial region in Europe.

Until recently, inventor ownership has been the norm, and universities in Japan and many European nations did not have TLOs. In addition, these nations had little visible university-derived entrepreneurship. National and regional governments, making a basic comparison of their system of higher education with that of the United States, came to believe that the their lack of commercialization through start-ups was explained by the absence of a BD-like mechanism. Of course, as many have noted, the performance of U.S. higher education results from its unusual decentralized structure and the long history of university involvement in local development (Mowery and Sampat 2005).

In Europe, each nation has its own policies and practices. Geuna and Nesta (2006) summarize the evidence for Europe in this way, "the rapid rise of academic patenting in the closing quarter of the twentieth century was driven more by the growing technological opportunities in the bio-medical sciences (and maybe also in ICT) and the feasibility of pursuing those opportunities in university laboratories, than by policy changes affecting the universities' rights to own patents arising from publicly funded research." In a revealing study, Valentin and Jensen (2007) compared Denmark and Sweden after Denmark passed BD-like legislation. In Denmark, the academic patents owned by industry decreased, while this was not observed in Sweden. This result suggests that Denmark disrupted the traditional pathways for university inventions to diffuse to industry and that this was not balanced by the formation of new pathways. These studies suggest that inventor ownership systems in Europe have successfully transferred technology without official university involvement.

The case of the University of Cambridge demonstrates that the inventor ownership model can successfully transfer technology while encouraging entrepreneurship. The European and Japanese experiences with inventor ownership also demonstrate

[12] There is no existing database to compare entrepreneurship across universities. A possible contender to this is China where the Chinese Academy of Sciences and elite universities have been the source of large numbers of spin-off businesses, both in technology and other fields (Chen and Kenney 2007; Lu 2000).

that TLOs are not necessary for technology transfer. Technology transfer does occur in environments without university ownership, and the University of Cambridge shows that this transfer can be substantial.

12.5.3 Weaker Ownership Rights Models

A requirement that all inventions generated through federal support be placed in the public domain or, in a less radical variant, only licensed on a nonexclusive basis has been suggested (Eisenberg 1996; Nelson 2004). Since nonexclusive licensing is a tax, and shifts the invention rents from one actor to another, this variant would socialize a part of the value of the inventions (Rhoten and Powell 2007). For basic process innovations, even in biology, an open strategy is more effective than either an exclusive, or even nonexclusive, licensing agreement in encouraging technological transfer and progress. The reason is that basic processes are not final products but are of principal use as an input into future research. The number of paths or directions this future research could follow, and the value of final outcome of these paths, is unknown. By restricting access to a basic process through exclusive licensing, the multiple paths these future research initiatives could follow are closed. Patents on the outputs of research do not have this problem; patents on research inputs do (Nelson 2004: 463).

In many engineering-based technologies, patents are not normally considered to be of great significance except to ensure cross-licensing (Cohen et al. 2000; Mansfield 1986). The greatest concern in a nonpatenting model would be for proprietary pharmaceutical compounds that might not be developed due to a lack of exclusive patent protection (Levin et al. 1987; Mansfield et al. 1981).[13] In an approach advocated by Nelson (2004) in defense of the scientific commons, exclusive patent protection would not be eliminated, but it would be limited to only those cases where exclusive licensing can be shown to be necessary for technology transfer. Currently, there is nothing in the language of BD that explicitly discourages exclusive licensing, just as there is nothing in the language that discourages universities from maximizing their licensing income. This approach has been picked up by So et al. (2008: 2081) to advance the following rule for countries contemplating legislation on university technology transfer: "Any BD-style legislation should be founded on the principle that publicly funded research should not be exclusively licensed unless it is clear that doing so is necessary to promote the commercialization of that research."

For the university, placing inventions in the public domain would ameliorate current concerns about commercialization's influence upon its mission and faculty. In many cases, it would lower the cost and reduce the uncertainty of using new

[13] The number of truly exclusive patents licensed by universities is quite small and as expected are for therapeutic molecules (Pressman et al. 2006).

university-developed technologies, thereby accelerating their adoption. Through a radical response to the difficulties of the current model, the public domain model provides an alternative reference point for considering other ownership models.

12.6 Conclusion

The Bayh–Dole system in the United States is an example of how organizational arrangements, once in place, soon appear to be natural and develop an aura of normalness that discourages critical evaluation. Today, not only in the U.S. but globally, the BD university ownership model is being framed as the "rational" and "natural method" for organizing the interface between university inventions, inventors, and the economic realm. Policymakers around the world have come to believe that if their universities are allowed to take ownership and market the inventions produced by the research that occurs in their laboratories that they will be blessed with high-technology economic development.

Despite the wide range of academic research on university technology transfer, it is remarkable that the fundamental theoretical and conceptual issues regarding the role and operation of TLOs in technology transfer have, until recently, been dealt with only in passing (for exceptions, see Litan et al. 2007; Mowery et al. 2004; Powell et al. 2007). In this chapter, it has been shown that for many important university inventions, particularly basic procedures with wide application, patents and TLO management are unnecessary for their diffusion and adoption. This was certainly the case for the C–B technology and the Axel co-transformation process (So et al. 2008; Sampat 2006).

In other cases, the university ownership model may impede diffusion of technology. This impediment arises because in too many cases in the university ownership model, the TLO, which owns the invention, is the least knowledgeable actor in a licensing relationship. This informationally disadvantaged position can foster ineffective decision making, unreasonable demands, and/or procrastination. The result of such an unfortunate situation may be that inventors extend limited cooperation in the commercialization effort, or they may circumvent the entire university disclosure process and choose the gray market, or they may simply not bother with the process at all.

The alternative models of university technology transfer discussed here, the inventor ownership model and the weaker ownership rights models, differ from the current BD system. Moreover, although these alternatives also differ from each other with regard to the ownership of IP, they do share a common feature by specifically advancing the following objective found in the preamble of the BD of 1980:

> It is the policy and objective of the Congress…to ensure that inventions made by nonprofit organizations and small business firms are used in a manner to promote free competition and enterprise without unduly encumbering future research and discovery.

The weaker ownership models are oriented toward university inventions that are basically inputs to future research, while the inventor ownership model applies to those inventions where patenting and exclusive ownership are the best means to assure technology transfer.

In the inventor ownership model, the invention remains the property of the inventor or inventors to commercialize or dispose off through any solution they choose, including placing it in the public domain. This model places the inventor, someone very knowledgeable about the invention, in the position of deciding the proper approach to technology diffusion. If there is a normative argument for rewarding the university or the Federal government, we suggest they could be compensated with a small nondilutable, silent partner stake in all ventures that professors may undertake in their fields of expertise. The university's role would be to ensure that the commercialization process was honest and transparent. Such a solution need not lead to the abandonment of the university TLO, as it could offer its services to the inventor for a fee. The university TLO would be placed on a self-supporting basis. Well-managed, service-oriented TLOs would certainly survive and thrive.

The public domain and nonexclusive license variants are also attractive. They escape the problem of inventor ownership by stipulating that university inventions would not be owned at all or would be licensed to all users. For a large number of inventions, such arrangements would be effective and efficient. The most often mentioned difficulty with either of these variants is that the exclusive ownership rents derived from patents would no longer exist, leading to the question of whether the invention would be commercialized. In these cases, as we have argued above, explicit ownership should be assigned to the inventors.

The foundations of the university ownership model and the model itself are fundamentally flawed. It is time for policymakers and scholars to explore other models and arrangements for maximizing the social benefits of university inventions. If there is reason to question the BD model's operation in the U.S. economy, then there is certainly reason for questioning it in entirely different environments. Our critique suggests that significantly more research be undertaken on technology diffusion at universities where inventor ownership is practiced. What are the difficulties experienced in such control regimes? Are there greater problems with conflicts of interest and other untoward activity? Can society reap the benefits of university inventions in weak ownership regimes? This chapter suggests a program of research that critically evaluates alternative university invention ownership models to seek the one that best maximizes the social benefit.

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Chapter 13
Cooperative Innovation in the Chinese Biotechnology Industry: An Analysis Based on Chinese and US Patents from 2000 to 2007

Yantai Chen

13.1 A Brief Introduction and Literature Review

Collaborative networks have long been central to the knowledge-based industries such as biotechnology, nanotechnology, and other emerging technologies (Powell 1996, 1998). The growth of knowledge-intensive industries has heightened the importance of networks in research and development (R&D) as well as product development and distribution (Powell et al. 2005). In the early stage of development in the biotechnology industry, a significant feature is the networking and interaction such as research partnerships, alliances between private and public institutions, and regional networks (Preverzer 2001, 2008; Assimakopolous 2007).

Another fundamental characteristic of the biotechnology industry is the close linkage with basic knowledge (Mcmillan et al. 2000; Lehrer and Asakawa 2004), with academic scientists involved in basic research regularly filing key patents and even founding their own start-ups (Murray 2002). The primary source of competitive advantage for US biotechnology firms is generally regarded as the advanced national science base (Porter 2000; Lehrer and Asakawa 2004).

In the early phase of the biotechnology industry, the focus is on the knowledge spillovers and an entrepreneurial spark in the later stage; and in emerging biotechnology clusters there is a tendency to path dependence, which means the preexisting conditions can have great impact on the competences in a region (Carlsson 2006; Preverzer 2008). The development of the German and Japanese biotechnology industries highlights the importance of public governance within national research institutions, the autonomy of the university/public research institution, and the historical role of the public sector generally (Lehrer and Asakawa 2004).

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For later comers, successful catch-up has historically been associated not merely with the adoption of existing techniques in established industries, but also with innovation, particularly of the organizational kind, and with inroad into nascent industries (Fagerberg and Godnho 2005). To avoid being stuck along an inferior path that never catches up (Nelson and Winter 1982), institutional instruments may be needed to compensate for some of these "later comer disadvantages"; in particular, firms in the developing country need "institutional instruments" to improve the linkage with the technology frontier, the linkage with markets and sophisticated users (Porter 2000), supply of needed skills, services and other inputs as well as the local innovation system or network (Fagerberg and Godnho 2005).

In order to build up an indigenous innovation system in China, the Chinese government invested massively on R&D, in particular the biotechnology, renewable technology and other emerging technologies after the new millennium, in order to catch up in the innovation industries and promote networking and cooperation in the biotechnology industry (Liu et al. 2008). Deficient of world-class basic research in its transition from beginning stage to rapid development, China has taken its own advantages as the "institutional instruments" to catch up, such as aiming at attracting scientists and directive locational policies (Preverzer and Tang 2006; Preverzer 2008).

Compared to the developed countries such as USA, EU member states, and Japan, emerging countries such as China tend to be at a disadvantage for developing knowledge-intensive industries such as the biotechnology industry due to the systematic weaknesses in the innovation network. However, in the period of 2002–2007, China has experienced rapid growth in the biotechnology industry, along with its double-digit GDP growth and the emphasis on indigenous innovation. Although the competitiveness of biotechnology industry in China is still not strong enough, it shows rapid growth.

In this chapter, we target to analyze the catch-up process of the Chinese biotechnology industry, its particular the pathway to build up an innovation network and conduct collaborative innovation based on its initial conditions and its own advantage. The remainder of this chapter is organized as follows. In Sect. 13.2, the collection of data and the methodology are presented, followed by the illustration of the brief history and current status of the Chinese biotechnology industry. From Sect. 13.3 to 13.5, the roles and interactions between domestic academia–industry, foreign biotechnology firms, and domestic biotechnology innovation system and the increasingly significant role of returnees are illustrated. In Sect. 13.6, the hampering factors for the Chinese biotechnology collaborative innovation network are identified. The concluding remarks and policy suggestions are given in last part.

13.2 Data and Methodology

To analyze the innovation capability and R&D dynamics of the Chinese biotechnology industry, we have collected some quantitative information from the database of the State Intellectual Property Office of P.R. China (SIPO) and United States Patent and Trademark Office (USPTO). The analysis is mainly focused on the period 2000–2007, a rapidly increasing period for Chinese biotechnology industry development.

For a detailed look at the history of Chinese biotechnology innovation and development, we also review the recent policies on the Chinese biotechnology industry and related issues. The information is collected via secondary resources such as web pages and annual reports published by the official and mass media.

To obtain first-hand and in-depth information, we also conducted 31 interviews with the senior managers/CEOs of the firms of different sizes and ownerships in Shanghai, China from March to May, 2007. Of them, 15 firms are founded by entrepreneurs who studied and/or worked abroad (especially in USA and EU) and then returned to China, i.e., so-called "returnees." To update their progress, we also trace their activities via searching the web pages and contacting via email or telephone in 2008 and 2009.

13.3 Status of Biotechnology in Mainland China

13.3.1 A Brief History of the Chinese Biotechnology Industry

The modern Chinese biotechnology industry came into existence from the 1970s. At the beginning stage till the end of 1980s, it was mainly based on research activities in the public research institutions, and some biopharmaceutical firms were founded as spinoffs of universities and public research institutions (MOST 2006). The entrepreneurs exclusively possess strong academic backgrounds, and they were also tightly associated with the network in the academia.

From the 1990s, there was a boom in Chinese biotechnology thanks to both the political will to push the development of biotechnology and the growth in demand. On the one hand, the establishment of dedicated national biotechnology centers facilitated the development and organization of important applied science projects in China. Progress was driven by the High Technology R&D Programme (863 Programme) and the National Basic Science (973) Initiative. On the other hand, in the 1990s domestic investors in China rushed into the biopharmaceutical industry, which resulted in a large increase in terms of biopharmaceutical firms. Due to high growth rates of the economy and a demand for medical products rising with it, sales of biotechnology-based drugs amounted to 6% of the total revenue of China's pharmaceutical industry in 2000 and were over two billion Euros in 2001.

Advancements in plant biotechnology, modernization of Traditional Chinese Medicine (TCM), and biopharmaceutical and embryological biotechnology in application-oriented and fundamental mechanisms have occurred from 2000s (Lakhan 2006). Instead of merely transplanting Western science, China has now begun to use modern biotechnology to solve national problems and to promote indigenous innovation. The combination of diverse plant germplasm and other resources, attracting Chinese scientists and entrepreneurs educated and trained

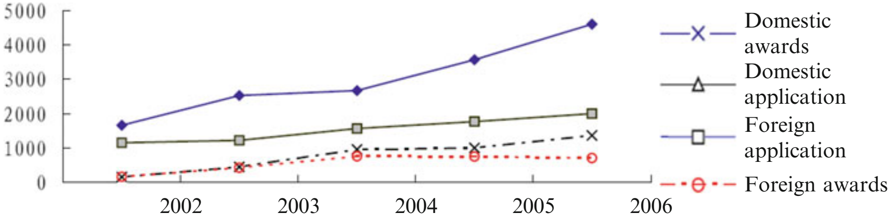

Fig. 13.1 Biotechnology patents' applications and awards in China (2002–2006)

abroad (so-called "returnees") or the Chun Hui Programme of 1996, and substantial government support in science bases and entrepreneurship have accelerated the development of modern biotechnology industry in China.

13.3.2 Facts of Biotechnology Industry in Mainland China

By 2007, the biotechnology firms in Mainland China were estimated to be 1,200, of whom around three-quarters were new-founded, of whom 614 firms have registered their patents in Mainland China (SIPO 2008), thanks to the government support for the entrepreneurship and massive returnees' engagement in the biotechnology industry after 2005. To make a comparison, in 2003, there were around 500 biotechnology firms in China according to the OECD report (OECD 2006). However, the true size of the Chinese biotechnology industry (especially innovation-based biotechnology firms) is difficult to gauge due to twofold reasons – for one thing, many companies label themselves as "biotech firms" or are labeled as "biotech firms" since they are located in the high-tech park, but actually they are only involved in processing of chemical components for pharmaceutical companies; for another thing, most industry reports do not make a differentiation between "pharmaceutical" and "biotechnology" industry (Sternberg and Müller 2005).

In the period between 2002 and 2005, China experienced a rapid growth in the biotechnology industry. This can also be seen from the patent registrations. In this period, the annual growth rate in patent applications reached 23.0%, with a rate of 29.0% in domestic patent applications and 15.1% growth in international patent applications (according to the International Patent Classification of OECD). In 2006, the applications in biotechnology amounted to 6,300 in the SIPO, China's official office for patents and trademarks, and the awards of biotechnology patents by SIPO reach 2,072, of whom 1,366 belong to domestic awardees, which is 9 times the awards in 2002 (156) with the annual growth rate of 720%, and 706 belonging to foreign awardees in 2006 with annual growth rate of 43.8% from 2002 (165) (Fig. 13.1 and 13.3).

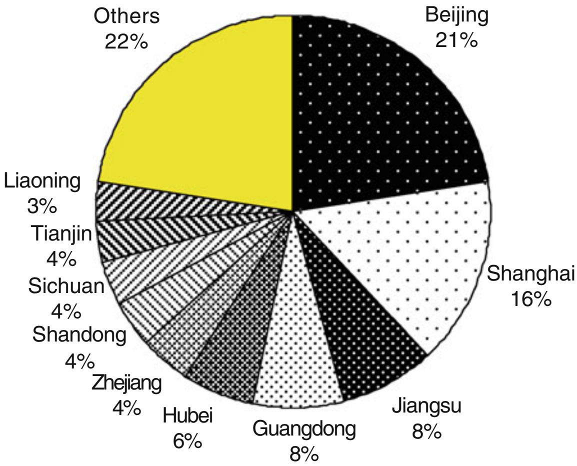

Fig. 13.2 Geographic distributions of biotechnology patents' awardees in China (2002–2006)

13.3.3 Geographic Distribution of Chinese Biotechnology Industry

There were three main clusters of companies and research organizations in biotechnology on the eastern coast of China, namely around Beijing (Pan-Bohai Region), Shanghai (Yangtze River Delta), and Shenzhen (Pearl-River Delta) according to the data from National Bureau of Statistics (2008) (Fig. 13.2).

In terms of Chinese biotechnology patents registered in the United States Patents and Trademarks Office, there is the similar distribution. The Beijing cluster contained the largest number of firms (177), followed by Shanghai (158), and Shenzhen with 126. In terms of size of firm and sectoral specialization, most of the Chinese biotechnology firms were small, with two-thirds having fewer than 100 employees. In terms of specialization, they were mainly involved in biomedicine/pharmaceutical, human health, diagnostics, and equipment sectors, followed by agriculture, chemicals, and services sectors (Table 13.2).

Looking at the patent output of Chinese biotechnology firms, there are several distinguished characteristics.

The ownership of Chinese biotechnology patents in the United States Patents and Trademark Office (USPTO) were dominated by foreign ownership or joint ventures. There were 157 US patents in biotechnology for Chinese firms between 1980 and mid-2006. Among them, nearly half (75) are wholly foreign-owned enterprises, 51 out of 75 are owned by US institutions, and 11 by institutions in the Asia-Pacific region. In the above-mentioned three clusters in the eastern coast of China, Shanghai took the lead in the domestic ownership of US patents (26) and Beijing followed with 13 US patents. Shenzhen only possessed two.

13.4 The Role of Domestic Academia–Industry Collaboration in the Chinese Biotechnology Industry

Universities and public research institutions have played a very important role in the biopharmaceutical industry in three ways (Liu and White 2001): First, Chinese universities and public research institutions also act as partners of knowledge base and knowledge creation in academia–industry cooperation. Second, these institutions also conduct technology diffusion by establishing spinoffs and selling technologies or licensing to industrial sectors (Kollmer and Dowling 2004). Moreover, Chinese universities and research institutions are developing new drugs and new biotechnologies directly, which is illustrated in Tables 13.1 and 13.2.

The role of Chinese universities and public research institutions in producing biotechnology knowledge and contributing to the biotechnology patents is becoming increasingly significant. In 2001, the universities and research institutions' patents' awardees accounted for 22% respectively, and the companies' awardees took the lead with a percentage of 38%. However, the percentages of companies' awardees decreased sharply from then on, with only 18% for the total biotechnology patents in China. Surprisingly, the universities and research institutions' patents' awardees accounted for 37 and 26%, respectively. This means Chinese universities and public research institutions are now becoming the center of knowledge creations in biotechnology systems in China in terms of patents' awardees (Fig. 13.3).

Table 13.3 illustrates that, by the end of 2006, the top ten Chinese biotechnology patents' awardees in China were not exclusively universities and public research institutions and eight out of ten are universities. To make a comparison, the top ten abroad biotechnology patents' awardees in China are all companies.

The establishment of biopharmaceutical spinoffs by universities and public research institutions is a very frequent phenomenon. Before 2003, the majority of the biotechnology firms were founded by universities and research institutions

Table 13.1 Sectoral distribution of Chinese biotechnology clusters in 2003

	Beijing cluster	Shanghai cluster	Shenzhen cluster
Bio-medicine/pharmaceutical	44	48	37
Human health	29	34	20
Agriculture	10	21	10
Biochemistry engineering	12	12	5
Environment	7	10	8
Instrumentation (diagnostics and reagents)	49	18	30
Marine	10	6	2
Services	7	7	4
Others	9	2	10
Total	177	158	126

Source: Ministry of Science and Technology of China (2005), from http://www.most.gov.cn/kjtj/tjsj/

Table 13.2 Structure of Chinese biotechnology patents in USPTO (the period of 1980–2006)

Typology	Number
Geography of Chinese biotechnology patent ownership	
Foreign	
USA	51
Asia-Pacific	11
Other	13
Domestic	
Beijing	13
Shanghai	26
Shenzhen	2
Other	17
Unclassified	22
Total	157
Inventor collaborations	
Domestic collaborations	64
Foreign collaborations	70
Chinese-named scientists abroad	40
Single inventors	23
Total	157
Institutional type of Chinese biotechnology patent ownership in USPTO	
Companies	78
Universities	43
Government	9
Individuals	7
Unclassified	20
Total	157

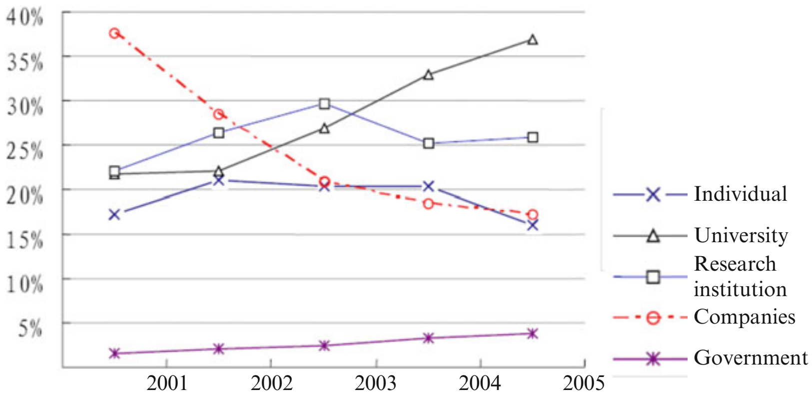

Fig. 13.3 Institutional structure for applying domestic biotechnology patents in China (2001–2005) *Source*: National Bureau of Statistics (2008), "Biotechnology Patents in China: facts and prospects", from: http://www.sts.org.cn/zlhb/2008/2.1.htm#4

Table 13.3 Top ten biotechnology patents' awardees in China (1980–2006)

	Domestic patents		Abroad patents	
Ranking	Awardees	Numbers	Awardees	Numbers
1	Tsinghua University	102	Ajinomoto Co., Inc.(Japan)	90
2	Zhejiang University	89	F. Hoffmann-La Roche A.-G. (Switzerland)	79
3	Research Institute for microbiology (CAS)	74	Panasonic Corporation (Japan)	63
4	Nanjing Agriculture University	69	Novo qi metz Co. Ltd. (Denmark/USA)	47
5	Zhongshan University	67	Yoshikubo Brewing Co. Ltd. (Japan)	37
6	Fudan University	61	Pfizer Inc. (USA)	34
7	China University of Agriculture	55	U.S. Research and Development Foundation (USA)	33
8	Shanghai Jiaotong University	54	BASF (Germany)	32
9	Wuhan University	52	Kyowa Hakko Kogyo Co. Ltd. (Japan)	31
10	Shanghai Research Institute for biochemistry (CAS)	49	SmithKline Beecham Biologicals S.A. (Belgium)	29
			Eli Lilly and Company (USA)	29

(Liu et al. 2008). Universities and research institutions commercialize their technology through joint ventures, in association with either industrial firms or governmental agencies.

Moreover, Chinese universities and public research institutions sell their technologies and patents via licensing strategies to industrial firms, according to our investigation in China in 2007. Usually, they do not have financial and market networks and production facilities to commercialize their products (Kollmer and Dowling 2004). By licensing or selling patents directly, universities and research institutions act as one of the most important type of nodes in the biotechnology innovation network in China.

In China, there is an increasing trend of academia–industry collaborations. In 2007, there were 26,292 units of patents' application in the biotechnology and pharmaceutical field; out of them 2,481 units are co-applications with two or over two institutions, accounting for 9.44% of all applications. Some applications between individuals or individuals and institutions are excluded, and among them 1,007 units are applications from different institutions. We analyzed all the 1,007 samples regarding the institutions (university, research institution, or industry) of the first two applicants in each unit. The results are illustrated in Fig. 13.4.

In the biochemical sector, the collaboration between industries takes the lead with 38% of all the patent applications from two or more different companies,

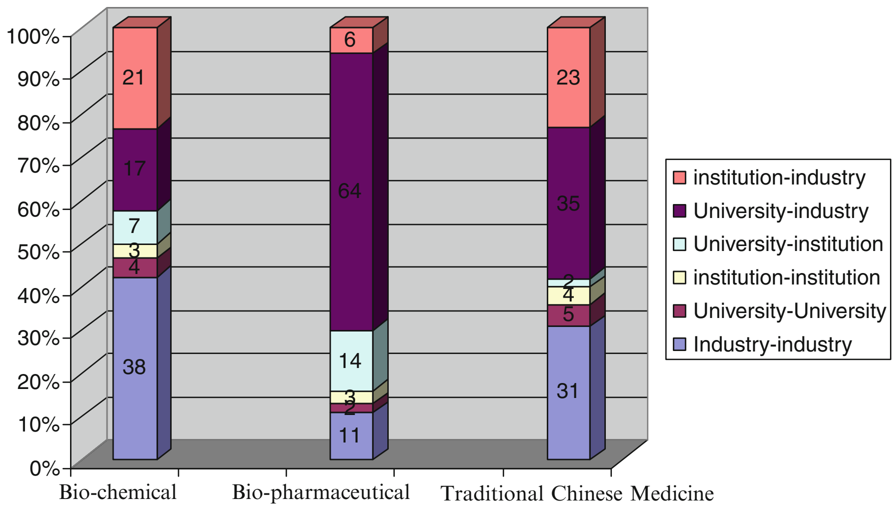

Fig. 13.4 Collaboration between academia–industry in the Chinese biotechnology sector (2007) ($n=1{,}007$)

followed by the collaboration between industry and public research institutes (21%), and cooperation between industry and university (17%); the other three formats of cooperation (collaboration between universities, research institutions, and university–research institution) appear to be less with only 14%.

Concerning the bio-pharmaceutical sectors (325 samples), however, collaborations between industry and university are the majority (64%). Pertaining to the first applicants, 289 out of 325 patent applications are universities, which shows in the bio-pharmaceutical sector that tends to university–industry collaborations, and in this process universities dominate taking the advantage of basic research capabilities. Again, in this sector, the room for collaborations between university and research institutions in basic research has great potential, with 14% of all the collaborations in the joint patents' application. The joint applications between companies are less with 11%. Surprisingly, research institution–industry collaborations only account for 6% of all samples.

As for biotechnology combining with TCM, the three most important collaborations are university–industry (35%), industry–industry (31%), and institution–industry (23%).

Another significant phenomenon illustrated in the Chinese patents in the USPTO (Table 13.2) is that a large number of patents are the domestic collaborations with no foreign involvement. A total of 64 patents out of 157 are inventions from domestic collaborations with no foreign involvement. This conclusion is different from the pattern before 2000; at that time joint patent applications among universities, research institutions, and firms were rare (Liu et al. 2008).

13.5 The Role of International Companies in the Creation of Biotechnology Knowledge

There has been a close linkage with US, Japan, and/or EU public institutes and reliance on foreign partnerships in the Chinese biotechnology industry. By 2006, the accumulated applications on biotechnology patents amounted to 37,300 units in China, around 3.4% of all the Chinese patents applications. Of them, 14,000 units were applications from abroad institutions, which accounts for 37.5%. In terms of biotechnology patents' awards, there were 8,011 patents in biotechnology, which accounts for 2.7% of all the Chinese patents by 2006.

Patents granted for non-Chinese/joint institutions reaches 3,405, or 42.5% of all the granted biotechnology patents in China (Fig. 13.5). Before 2002, foreign awardees took the lead as regards Chinese biotechnology patents' owners. This shows the importance of foreign institutions in the role of biotechnology development in China, though the percentage of non-Chinese owners is decreasing.

Taking an analysis on the characteristics of foreign owner in Chinese biotechnology patents, by 2006 USA took the lead with 30.8% of all the foreign biotechnology patents in China, followed by Japan (23.5%), Germany (7.2%), Switzerland (5.6%), UK (4.7%), South Korea (4.6%), Denmark (3.8%), France (3.6%), and The Netherlands (3.3%). EU members account for 28.5%, lower slightly than USA (30.8%), referring to Fig. 13.6.

USA, EU, and Japan account for 82.8% of all the foreign awardees of biotechnology patents in China by 2006. Regarding EU members, more than 80% patents were from Germany, UK, Denmark, France, The Netherlands, and Belgium.

From Table 13.2, we can find that collaborations between Chinese scientists and scientists abroad account for the largest proportion of Chinese biotechnology patents in the USPTO, with 70 out of 157 or 45%. Substantially among the 70 collaborations, 40 patents involved Chinese-named scientists working abroad, which means the development of Chinese biotechnology firms results largely from the participation of Chinese scientists abroad and their network with foreign research institutions.

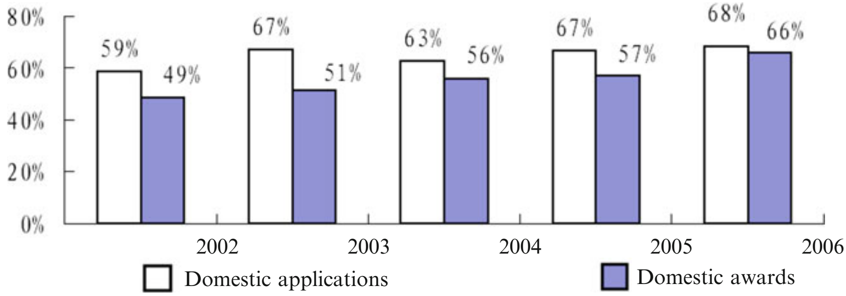

Fig. 13.5 Percentage of domestic/abroad applications and awards in biotechnology patents in China

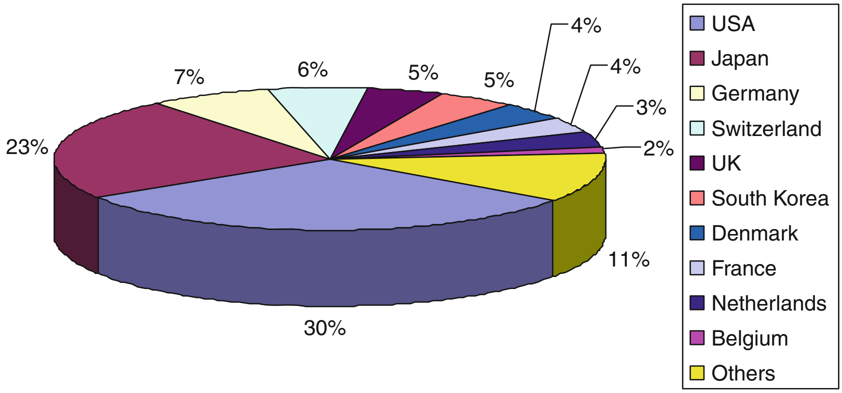

Fig. 13.6 Main foreign awardees of biotechnology patents in China by 2006

In terms of the distribution of institutional ownership of Chinese biotechnology patents in the USPTO, we can also see the role of international companies in the creation of biotechnology knowledge and commercialization (Table 13.2). Among the 159 patents, around half were companies owned, which means industry is becoming the real innovator. The universities, research institutions, and government sectors are of great significance too, partly due to the joint research between Chinese and American or EU public research institutions and universities (Preverzer 2008).

13.6 The Increasingly Significant Role of Returnees

Chinese returning scientists, who study biotechnology and/or work in the related firms, universities, or research institutions abroad (especially in USA and EU), play a significant role in contributing to the development of modern biotechnology in China after 2000. They both create linkages with foreign companies and research institutions abroad and act as founders of biotechnology start-ups or senior managers in incumbent biotechnology firms.

The creation of new biotechnology firms in the existing clusters took off after the launching of the "Chun Hui Initiative" in 1996, the policy to "Encourage overseas scholars to serve the country in different ways," and the recent initiative "suggestions on supporting senior overseas scholars" under the global financial crisis since 2008. There has been a favorable environment for returnees to set up their own business in Returnee Parks or work in universities and public research institutions (Preverzer 2008). It is estimated there are over 1.3 million students going abroad to study since 1978, over 30% of whom have been in the field of biotechnology or related areas (Qi 2003; People's Daily 2008). More and more overseas students returned to China to find opportunities with the rapid development of China since 1992.

Chinese returnees integrate into the international innovation network of biotechnology relying on both formal and informal ways.

13.6.1 Formal Knowledge Flows Internationally

On the one hand, returnees in the field of biotechnology need to have a technology or patent before they return to China if they want to apply for some prior support in China. Accordingly, the founders have either licensed some research results in biotechnology and came back to China to develop them into marketable products or commercialized their technology/patent in USA or EU and then brought them back to China.

Direct involvement in world-class biotechnology knowledge base. Some biotechnology firms in China are also present in the USA or EU at the same time, as the entrepreneurs are employed either at a Western university or company. In such arrangements, China can get access to world-class quality research, and partly the coordination of activities in China is located in USA or EU.

Research and development divisions between China and Western. Some biotechnology firms founded by Chinese returnees are collaborating with companies in USA or EU (Sternberg and Müller 2005). There are complementary competencies between the Chinese partners and their Western partners. In terms of the global value chain (Geriffi 2003), USA or EU take the lead in research, with mature technology or patents; then they outsource some processes to be done with competitive cost advantages in China. Some equivalent pathways are each company in EU, USA, Japan or China, and India specializing in part of the drug discovery and development process.

13.6.2 Informal Knowledge Flows Internationally

On the other hand, with the help of Chinese returnees, Chinese biotechnology industry and research institutions have close informal linkages with international biotechnology networks.

Scientific knowledge flows in the informal network. Most of the returnees keep close contacts with their original hosts in USA or EU. Some live in the USA or EU for several times per year, while most of them travel frequently to participate in international conferences. This enables Chinese returnees to get access to state-of-the-art knowledge.

Market knowledge flows in the global network. As some Chinese companies cater to foreign customers directly, they can get first-hand knowledge of customer requirements and improve their product.

13.6.3 Integration into Domestic Knowledge Network

Chinese returnee entrepreneurs or professors in biotechnology also set up close cooperation with domestic universities and research institutions. Most of the biotechnology companies have qualified human resources and a variety of instruments, equipments, and laboratories which one individual firm cannot afford to buy or may have low usage efficiency if buying per se.

Training and recruitment of qualified domestic personnel. Many Chinese returnees can get offers of a professorship or a leading position in a domestic university or research institution due to their world-class expertise in biotechnology. Returnees hold lectures or help to establish new courses of studies; thus scientific staff or research students will obtain new knowledge and learn new methodologies. Returnees also can train Ph.D. and masters' students, and even Post-Ph.D. working stations in their companies or university/research institution laboratories. In this way, they can employ these new-trained researchers. Even if the research students do not work further in their companies or labs, there is the knowledge spinoff effect.

Engagement in domestic research projects. Since the returnees can use pubic instruments, equipments, and laboratories which they will not or cannot afford to buy in China, they can engage in research projects jointly with Chinese universities or public research institutions. This is conducive and relevant for their firms' R&D as they use these entailed infrastructure for a low price. Domestic universities and research institutions can also benefit from the knowledge spinoffs from these returnees.

Clinical knowledge flows. Some firms founded by returnees also involve drug development and clinic studies in the later stages. It is of significance as regards working with domestic hospitals. In this process of clinical trials, Chinese hospitals can also learn from this type of collaborations.

13.7 Challenges of the Innovation System in the Chinese Biotechnology Industry

In the Chinese biotechnology innovation network, universities and public research institutions play active roles in R&D activities, working closely with biopharmaceutical firms in various forms especially after 2000 with the push and promotion of government policies. However, there are also many challenges Chinese biotechnology firms have encountered.

First, the innovation network of the Chinese biotechnology industry is characterized by a low density. In 2007, of all the 26,292 units of patents' application in the biotechnology and pharmaceutical field, only 2,481 units are co-applications with two or over two institutions, accounting for 9.44% of all applications – that means the majority of biotechnology firms are excluded from the innovation network. This is quite different from the situation in developed countries.

Second, even though the innovation network in the Chinese biotechnology industry has been established, the academia–industry networks are the main players, instead of industrial companies. From the patents between 2002 and 2006 in China, we can see that the top ten Chinese domestic patent applicants and awardees are exclusively universities and research institutions. It is exciting to see more and more collaborations initiated by Chinese domestic firms particularly in 2007, but it takes at least 5–8 years to see the plausible changing trend in China. Currently, the majority of Chinese biotechnology firms do not sell new-to-world or new-to-China products without involvement of innovation activities. Take for example, 97% of Chinese drugs on the market are Western medicines or generics. Most of them develop technologies aimed at upgrading existing products or products with low development risks (Sternberg and Müller 2005).

The above-mentioned phenomenon also results from the third reason – weak intellectual property rights (IPR) system. This weak system is the obstacle for biotechnology firms to grow and innovate. Although the Chinese government has enforced extensive protection of IPR to encourage innovation, it is still difficult to execute when it comes to practice due to its complex system and contradictions. Consequently, the international biotechnology firms in China as well as "returnees" are unwilling to collaborate with domestic firms. This can explain partly why the knowledge flow between domestic firms and international firms is rare.

Another reason hampering the development of the biotechnology industry in China is as in other countries: lack of enough financial support. What differentiates China is the "Chinese government-pushed innovation system," i.e., China concentrates most of its R&D budget within state-owned industries, or "plans" to dispense the R&D budget to the innovative big firms or start-ups. This tends to cause to a political lock-in (Sternberg and Müller 2005), i.e., it is more apt to talk of "Guanxi" (Chinese relationship) between the government and innovative firms. Local bureaucracies, therefore, tend to intervene on behalf their own interests, instead of supporting innovative biotechnology firms who focus less on creating such "Guanxi" activities.

13.8 Conclusions on Biotechnology Innovation in China

This chapter traces the emergence of modern biotechnology innovation in China, particularly after 2000. From 2002 to 2007, China has experienced a rapid growth in biotechnology industry in terms both of the number of biotechnology firms and patent applications and awardees. There concludes four main points.

The first point is, the collaborative innovations in the Chinese biotechnology network are strengthened, in particular the linkages between university–industry and research institution–industry both in China and its linkage with international networks. Domestically, however, universities and research institutions, especially the former, dominate in the collaborative innovation in domestic patents. This does mean that in China, the collaborative innovation tends to be academic oriented. The Chinese domestic industrial actors show less innovative capabilities. To make a comparison, foreign biotechnology firms in China have much stronger innovation capacities in terms of patent registrations. Internationally, the Chinese universities and foreign companies play the key role in the collaborative innovation network. The close connections between Chinese universities and internationally renowned universities, and the positive role of returnees as "frontier knowledge carriers" to some extent function as the "institutional instrument," as Fagerberg and Godnho (2005) pointed out.

Second, the Chinese returnees, playing significant roles in the biotechnology innovation and collaboration of knowledge creation and transfer, contribute to the rapid development of the Chinese biotechnology industry with the supply of needed skills, services, and other inputs as well as the local innovation system or network. These are the other two "remedies" for the "institutional instruments," which are the short boards of the Chinese biotechnology innovation system to catch up world biotechnology leaders. Returnees can benefit from the sharing the expensive instruments and laboratories with low costs and the costs of qualified personnel in China when they join the universities and research institutions, or join the collaborative research. In turn, under their supervision and training, the Chinese employees or partners can improved their skills, reducing the gaps with developed countries. They also can act as significant strong and weak ties (Powell and Grodal 2005) among international and local networks in the innovation systems. The problem is, only some junior scientists such as post-Ph.D. or young scholars abroad are attracted and return, but the senior scientists and experts with management skills necessary for enterprises are less interested (Preverzer 2008), due to the less developed Chinese innovation system and absorptive capabilities (Cohen and Levinthal 1990). The current Chinese policies to support returnees also lack consistency.

Third, the linkage with international markets and sophisticated users is possible with the roles played by returnees and international biotechnology companies in China. As for the biotechnology firms founded by returnees, some divisions are present in China, and also being present in the USA or EU at the same time. This enables their products' exposure to the sophisticated users and penetration into international markets. In this process, the companies founded by returnees can learn from the supplicated international users (von Hippel 1988; Morrison et al. 2000) and tend to force the Chinese manufacturers or R&D divisions to upgrade their processes or products since they put their manufacturing center or R&D branches in China (Geriffi 1999; Grogory and Shi 2007). On the other hand, the international biotechnology companies in China also contribute to the international markets and woo the sophisticated users. However, the role of these players is less significant, since most of the international firms focus on domestic Chinese consumers or south Asian markets with less sophisticated users. Moreover, there are rare interactions between international companies and domestic Chinese biotechnology firms. Returnees also have fewer interactions with domestic firms due to worrying about the loss of intellectual property.

Finally, point is that a weak IPR system is the bottle neck of the Chinese biotechnology innovation system. Not only are the international companies unwilling to collaborate with domestic companies, the returnees also have rare interactions with their Chinese domestic partners; thus this leads to the less knowledge flows among the Chinese biotechnology industry innovation networks. This also can partly explain why domestic Chinese biotechnology firms tend to be less involved in innovation activities. This is a vicious circle.

13.8.1 Policy Suggestions and Notes on International Collaborations

Although the IPR issue is a long and frequently-mentioned topic in the Chinese innovation system, current research provides little guidance on the potential contributions of an internationally strong patent system to the prospects for "catch-up" by the less developed countries like China. Analyzing in nineteenth century USA or the Japanese economy of the 1950–1980 period, a certain amount of "free-riding" under a weak IP regime may lead to successful catch-up (Granstrand 2005). The problem is, with the ever-increasing innovative activities in China, a protection system is urgent for China to build up an indigenous country. This will benefit China in the long run. The Chinese government has enacted a package of IPR laws by 2008; the key to the current situation is to enforce the laws. This entails the collaborations of individuals, companies, associations, the government, and other societies.

Promoting scientific entrepreneurship is another key consideration in policy making. Since the majority of domestic patents and innovation activities are conducted in universities and research institutions, and it is still long process to promote industrial-oriented innovation, the promotion of scientific entrepreneurship seems to be another solution (Olofsson et al. 2008). Policy makers can consider putting academia close to venture capitalist and other networks, and provide the opportunity for more business experience or allow academics to work as entrepreneurs as well as keeping their position in professorships.

It is also important for policy makers to design the incentive mechanisms of encouraging domestic linkages, providing financial supports particularly the angle investments while loosening the controls in the later stages. Attracting senior scientists or experienced managers in this field and maintaining the consistency of policies are of great importance. At the same time, improving absorptive capabilities via encouraging indigenous innovation and alliances with the ever-improving IPR environment would be also policy priorities.

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Chapter 14
How Leading Firms Manage Product Safety in NPD

Andy Yunlong Zhu, Dimitris G. Assimakopoulos, and Maximilian von Zedtwitz

14.1 Introduction

Product safety is a big concern in the modern society. Every year, hundreds of millions of consumer products are recalled from the market in the United States and Europe for safety reasons. According to CPSC (Consumer Product Safety Commission), there were 448 recalls for consumer products in 2007 in the United States and 231 recalls (52% of total recalls) alone were for juvenile products (KID 2008). Among the products recalled, most of them were manufactured in China. According to the study of Beamish and Bapuji (2008), at the end of the third quarter of 2007, Chinese toy imports accounted for 88.2% of toy imports to the USA and 95% of the toys recalled in the market were made in China. Product failure can be due to defective design, manufacturing error and failure of information (Abbott and Tyler 1997). About 70% of all recalls can be traced back to shortcomings in product development (White and Pomponi 2003; Bapuji and Beamish 2008; Beamish and Bapuji 2008). Therefore, product development carries a large share of the responsibility for faulty products – not just manufacturing.

When we look at the NPD management literature, only little empirical research focuses on product safety. There are numerous publications on NPD practices and success factors (Zirger and Maidique 1990; Roussel et al. 1991; Ransley and Rogers 1994; Griffin 1997; Cooper and Kleinschmidt 1995, 2007; Cooper et al. 2004a–c; Barczak et al. 2009). None of them explicitly address the relationship between NPD practices and product safety. Thus, there seems to be uncharted territory both in theory and practice with respect to NPD practices and product safety. The purpose of this paper is to explore the NPD practices that are critical to product safety

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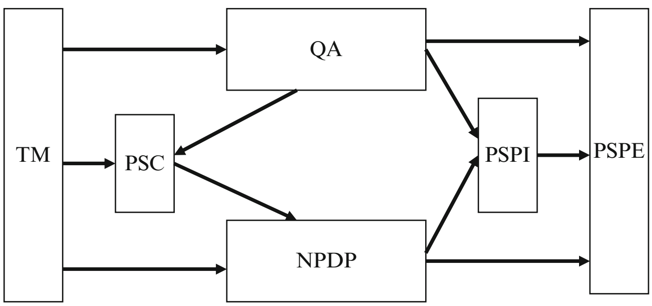
through in-depth interviews with 30 senior managers in 24 leading firms in the juvenile products industry. In Sect. 14.2, we review the literature on NPD practices and product safety management. Section 14.3 explains the methodology. The results and discussions are described in Sect. 14.4. In Sect. 14.5, we present the conclusions, implications for researchers and practitioners, and recommendations for future research.

14.2 Literature Review

Much has been written on NPD practices and success factors in the literature (Zirger and Maidique 1990; Roussel et al. 1991; Page 1993; Ransley and Rogers 1994; Griffin 1997; Cooper and Kleinschmidt 1995, 2007; Cooper et al. 2004a–c). However, these studies didn't address the implications of the NPD practices and product safety performance. It appears that the NPD management community didn't pay much attention to product safety. On the other hand, when we look at the literature in the safety community, most of them focus on the technical side for safety management, such as FTA (Fault Tree Analysis), FMEA (Failure Mode Effect Analysis), PHA (Preliminary Hazard Analysis), HACCP (Hazard Analysis and Critical Control Point), Risk Management, etc. (Main and McMurphy 1998; Ryan 1988; Main 2004); or on the occupational safety culture(Brown and Holmes 1986; Cox and Cox 1991; DeDobbeleer and Beland 1991; Hofmann and Stetzer 1996; Zohar 1980, 2000). In this study, we adopt the conceptual model for NPD practices and product safety (refer to Fig. 14.1) identified in a working paper by Zhu et al. (2010). We review the literature in the following areas in this section: top management support to product safety (TM), the role of quality department on product safety (QA), the firm's product safety culture (PSC), NPD team organization and resources, training on product safety, and NPD process (NPDP).



Remarks: TM – Top Management Support; PSC – Product Safety Culture in NPD; QA – Quality Assurance; NPDP – NPD Process; PSPI – Internal Product Safety Performance; PSPE – External Product Safety Performance

Fig. 14.1 Conceptual model – NPD practices and product safety

14.2.1 Top Management Support to Product Safety

Top management plays an important role in product safety. They set the firm's policies, objectives, and strategies for product safety. They devote necessary resources to achieve the goals. Much has been written about the importance of product safety policies and top management support to product safety (Heinrich 1931; Blake 1943; Kolb and Ross 1980; Roland and Moriarty 1983; Eads and Reuter 1983; Kitzes 1991; White and Pomponi 2003; Ryan 2003). However, most of them are anecdotal and prescriptive.

14.2.2 Role of Quality Department

Traditionally, the responsibility of managing product safety lies in the quality department. Among other responsibilities, they are in charge of product safety management initiatives, hazard analysis, product safety test, product safety review etc. Therefore, the role that quality team plays in safety management is apparent. Saraph et al. (1989) identified the role of quality department as a critical factor for quality management. Eads and Reuter's study (1983) revealed that it's commonplace to have formal product safety function and activities in the firms in United States, but there are no universal way to organize product safety function. The study also reported that the level of resources devoted to product safety at the corporate level seemed surprisingly small. They concluded that an appropriate matching of activities, resources, and commitment are the key to the effectiveness of the product safety activities.

14.2.3 Product Safety Culture in NPD

PSC is a set of norms and values shared by the organization toward product safety. Having a supportive PSC in NPD is critical to achieve good product safety performance (White and Pomponi 2003). In the safety management literature, most of the studies on safety culture focus on occupational safety culture instead of PSC (Brown and Holmes 1986; Cox and Cox 1991; DeDobbeleer and Beland 1991; Hofmann and Stetzer 1996; Zohar 1980, 2000). Eads and Reuter's study (1983) revealed that most firms have corporate safety officer reporting to the top leader of the organization. White and Pomponi (2003) also found 90% of best performing firms have dedicated, senior position staff (normally vice president level) focusing on product safety, regulatory, and environmental issues. Kitzes (1991) and Goodden (1995) also pointed out the importance of having a senior executive in charge of product safety who is independent of engineering, production, and distribution. The person should have the authority to gather information across technical functions and report to top management. Both think the position should be neutral and independent to avoid comprise on injury control. Many product safety experts also suggest firms to create an independent safety review team and process (Kitzes 1991; Nelson and Eubanks 2005; Goodden 1995).

14.2.4 NPD Resources

Having adequate NPD resources is important to the NPD success. Cooper and Kleinschmidt (2007), Cooper et al. (2004b) reported that most firms don't have enough NPD resources. Eads and Reuter's study (1983) indicated that most firms didn't devote enough resources in corporate product safety function. Not only is inadequate resource prevalent, training is also not enough. Training for employees on product safety requirements is crucial to improve product safety (Main and McMurphy 1998; Gookins 2005). However, according to the study of Main and Frantz (1994), most design engineers didn't receive formal training in safety management tools. This will affect the engineers' capability to improve product safety.

14.2.5 NPD Process

Numerous studies revealed that a formal and well-executed NPD process is a best NPD practice (Cooper and Kleinschmidt 1995, 2007; Griffin 1997; White and Pomponi 2003; Cooper et al. 2004b; Barczak et al. 2009). Having a high quality NPD process with thorough review, acceptance criteria, and deliverables at each stage is the strongest practice in the best performing firms. Another best practice reported in the literature is cross-functional team for NPD (Griffin 1997; Cooper and Kleinschmidt 1995, 2007; Cooper et al. 2004c; Barczak et al. 2009). Hodges et al. (1996) claimed that it's important to use cross-functional design team to ensure product safety, especially the product safety specialist should be involved starting from concept stage. Main and Frantz (1994) also supported that safety professionals should be involved in the design at the earliest possible and recommended to use concurrent engineering as a mechanism to ensure product safety.

Understanding what the customer wants is critical to the success of the NPD. Numerous studies cited VOC (Voice of Customer) as a key success factor (Griffin and Hauser 1993; Cooper and Kleinschmidt 2007; Cooper et al. 2004c). However, product safety as an "unarticulated need" and "must have" might be overlooked in the VoC analysis. Some engineers think if the product meets the safety standard, it's safe by definition. However, most of the time, safety standards are often behind state-of-the-art. It's the minimum requirements (Kalin 1994). When defining the product safety requirements in NPD, other information such as competitive product analysis, reasonably foreseeable use and misuse, and failure history for similar products should be considered besides relevant regulatory standards.

Product safety review. Governments and courts expect firms to fully test their products before putting them to the market (Goodden 1995). Performing adequate product safety testing and conducting product safety review at each stage of the product development is critical to safety. In general, product safety review is carried out by an independent product safety team to review the product in the following aspects: (1) potential hazards (hazard analysis); (2) warnings needed; (3) safeguard/safety device; (4) potential/foreseeable misuse. It differs from design review which focuses more on manufacturability, functionalities, performance, components/material, features, serviceability, cost, instruction manuals, etc. Product safety management practitioners argue that product safety review is vital to product safety performance (Kitzes 1991; Kalin 1994; Goodden 1995; Abbott and Tyler 1997; Nelson and Eubanks 2005; Main 2002; Christensen 2003). They suggest firms to establish complete product safety test and reliability test, to create an independent safety review process, and to conduct thorough safety review to assess the compliance with regulatory requirements and risk of injury by considering the hazards, the environment, and foreseeable use. However, most of these are prescriptive and there are no empirical evidences to support the claims. Main and McMurphy (1998) summarized the different approaches that design and safety communities applied to address product safety. In the design community, safety factors, safety checklist, personal experience, and industry or government standards are common practices. These approaches only focus on some elements of the safety problem and can be potentially limited when dealing with new design. In safety community, a more systematic approach is used, (1) define the system, (2) identify hazards, (3) assess hazards, (4) resolve hazards, and (5) follow up (Roland and Moriarty 1983). At the "resolve hazard" stage, the classic hazard control/elimination hierarchy is commonly used: (1) eliminate the hazards through design, (2) guard against the hazard, (3) warn the user about the hazard, and (4) train the user to avoid the hazard. Product can be safer through applying the techniques used in the safety community.

Supplier involvement in NPD process. Supplier involvement in NPD contributes to quality performance (Lascelles and Dale 1989; Saraph et al. 1989; Carter and Ellram 1994; Primo and Amundson 2002; Handfield and Lawson 2007). Handfield and Lawson (2007) found three-quarters of the respondents reported a smooth ramp-up to full production as a result of the supplier's involvement in their research. Primo and Amundson (2002) found that all product quality components of Garvin's eight dimensions of quality except durability and serviceability have strong relationship with supplier involvement. Unfortunately, product safety was not explicitly mentioned in their study.

NPD tools. The effective use of NPD tools has been an important element of managing integration in the NPD process. FTA and FMEA are considered two important and valuable risk management tools for product development (Abbott and Tyler 1997; Nelson and Eubanks 2005). In the research of Barczak et al. (2009), they reported only 48% of the best performing firms use FMEA. Thia et al. (2005) found that most of industrialists quoted time as a major factor influencing the use of the NPD tools. The study of Main and Frantz (1994) revealed that most design engineers didn't receive formal training in safety methodologies (such as FTA, FMEA, etc.) common to the safety community.

14.3 Methodology

In this section, we explain the data collection of the study. The research, which is part of a large study to identifying critical factors that affect product safety in the juvenile product industry, is to understand what are the critical-to-safety NPD practices of the leading firms. Therefore, we adopt case study approach, which is more appropriate for exploratory research (Voss et al. 2002). Based on a survey jointly conducted with China Toy Association (CTA) in the juvenile products industry in October and November of 2008, we selected the firms (or their parent firms and overseas subsidiaries) with a rating of "very satisfactory" or "satisfactory" for external product safety performance as target firms for interview, which we refer as leading firms. These firms normally have big names and renowned brands in their markets or around the globe. When we selected the interviewees, we purposely chose different nationals in these firms to gain global views and valuable insights from different perspectives. 34 senior managers in charge of product safety management in these firms were contacted with an email introduction, 30 respondents from 24 firms accepted the interview. The other four persons contacted either didn't reply to my email or couldn't schedule the interview within an appropriate time period. Three interviewees chose to provide detailed responses in writing. By adopting semi-structure approach, interviewees are allowed to explain their perceptions as they choose while centered around the standard questions to ensure the focus of the research. Each interview took one to one and half hour. An interview guide which has 34 questions(most of them are open questions) and covers all aspects of product safety management was sent to each interviewee in advance to ensure the interviewees are well prepared before the interview. In this analysis, we only use data related to new product development.

All interviews were conducted by the first author between July to November 2009. Four interviews were conducted through telephone; three people responded through e-mail; and the rest twenty three interviews were conducted through face to face meeting either in USA or China. All the interviews were tape recorded and transcribed by the first author.

Eighty-four percent of the interviewees are senior quality managers in charge of product safety management in the companies. The rest include senior managers from R&D, engineering and product management. In terms of nationality, 47% of the interviewees are from mainland China, the rest are from Europe, USA, Australia, Japan, Hong Kong, and Taiwan. In terms of product category, 4 interviewees are from toy companies and 26 interviewees are from firms making childcare articles and juvenile equipment. Based on the origin of firms, 40% are from mainland China, Hong Kong and Taiwan, 26% are from USA, 24% are from Europe, and 7 and 3% from Australia and Japan respectively. Please refer to Fig. 14.2 for the profile of the firms and interviewees. We had promised confidentiality before

Table 14.1 Critical to safety NPD practices used in leading firms

A. Top management support to product safety
Top management holds regular meeting to review product safety issues
Top management gives higher priority to safety vs. cost and schedule
Top management defines strategy, policy, and goals for product safety
Top management involves personally in making decisions on safety issues
Top management promotes product safety in all occasions
Top management kills the project if there are potential safety concerns
B. Role of quality department
The quality department head reports to the top leader in the organization
The firm has professional safety engineers in charge of safety analysis
The quality team has high visibility and autonomy
The quality team has the authority to hold projects/products if there are product safety concerns
The firm participates in establishing product safety standards for the industry
C. Product safety culture
The firm considers product safety is No.1 priority
A senior person in charge of product safety who is independent of production and distribution and can access to the top leader in the organization
There are incentives (such as CEO quality award) to promote product safety
There is a product safety committee to oversee all product safety management programs
D. NPD team organization and resources
The firm uses cross-functional team for NPD project with members from R&D, engineering, quality, manufacturing, sales, marketing, purchasing, etc.
The firm practices concurrent engineering (quality/safety and manufacturing engineering participating in the earlier stage of NPD process)
The NPD team is accountable for the success or failure of the projects
The firm has adequate NPD resources
The firm provides formal training on product safety for all relevant employees
Design engineers and quality engineers are required to study product safety standards and pass examinations
The firm provides training for design engineers and quality engineers on safety management tools such as PHA, FTA, FMEA etc.
E. NPD Process
The firm has a formal NPD process incorporating product safety requirements, product safety review, and acceptance criteria at each stage
The firm has well-defined robust product safety requirements, which provide enough safety margin and include regulatory requirements and the firm's own internal requirements
The firm has thorough product safety review (PHA/FMEA) at each NPD stage
The firm has in-house product safety testing and all products are third party tested before release for production
The firm conducts thorough reasonably foreseeable misuse and abuse analysis
The firm conducts field test
Design engineers consider product safety in the design process
The firm promotes design for manufacturability
The firm involves customer in NPD
The firm involves major suppliers in NPD
The firm has postlaunch batch testing/review procedure
The firm uses risk management tools such as PHA, FMEA, FTA

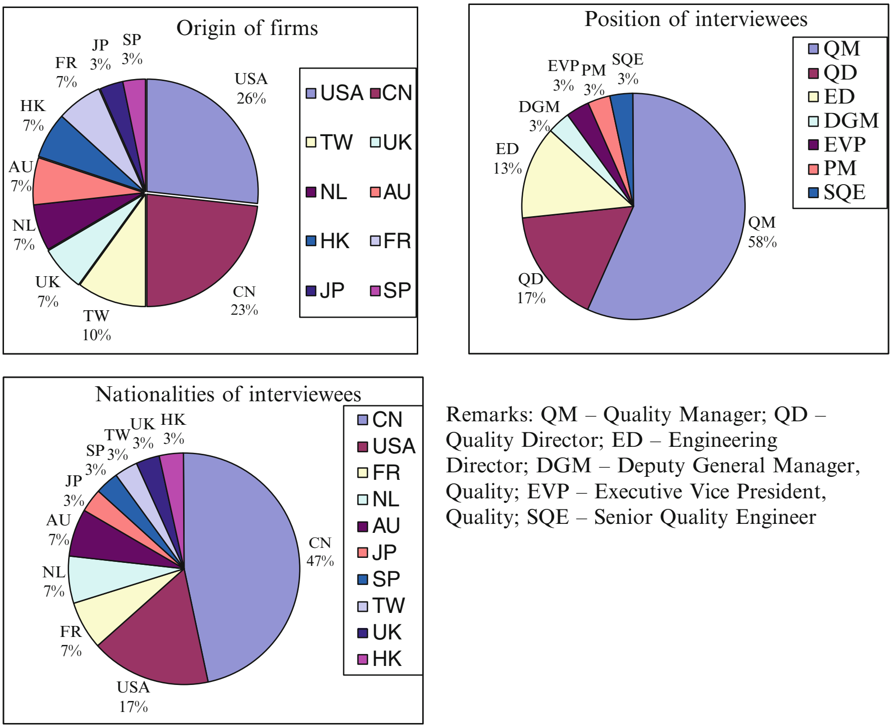


Fig. 14.2 Profile of interviewees and firms

the interview, so in the analysis, the names of the firms and interviewees won't appear. We use "I+sequential number" to represent the interviewees.

The interviews for USA, Europe, and Australian nationals were conducted in English. The rest were done through Chinese (an interpreter helped when we interviewed the Japanese). All the interviews were transcribed by the first author to facilitate data analysis. Transcripts of the interviews were sent back to the interviewees to check for the accuracy of the interpretation. This is a very important step as the results and analysis are based on the responses of the interviewees. Nvivo eight software was applied to assist data analysis.

As Yin (1994) argued case research is based on analytical generalization, rather than statistical generalization. The results should be considered exploratory and exemplary. Although we tried to include interviewees from different nationals with different background to make the results more representative, we cannot generalize the findings due to the methodological limitations.

14.4 Results and Discussion

14.4.1 Top Management Support to Product Safety

A very obvious observation from the interviews is that the top management pays a lot of attention to product safety issues. They set product safety policy, strategy and goals, and devote resources to achieve the objectives. This is in line with the claim in the literature (Heinrich 1931; Blake 1943; Kolb and Ross 1980; Roland and Moriarty 1983; Eads and Reuter 1983; Kitzes 1991; White and Pomponi 2003). The most prevalent practices to show top management support to product safety that we observed in the interviews are listed in section A of Table 14.1, which are quite similar to the quality management practices identified by Saraph et al. (1989) in their research. In general, both international and Chinese firms interviewed pay a lot of attention to product safety. On the other hand, compared best performers with good performers, the former shows much more commitment to product safety by top management than the latter. Below are some examples of comments from the interviewees:

- "The GM and upper management pay a lot of attention to product safety issues and hold regular meetings to review safety issues. They are involved personally" (I1).
- "They (top management) set the direction for product safety. They are concerned on product safety more than anybody else. They emphasize product safety in all occasional such as regular review meetings, company magazines, etc."(I13).
- "Depending on the management, when business is good it's easy to build in safety. When business is not very good, they're looking into cost cut, it will still be in compliance (with regulatory requirements). It goes on cycles…" (I10).

14.4.2 The Role of Quality Department

In all firms interviewed, quality team is in charge of managing product safety. Among other responsibilities for quality management, they're responsible for defining QR (Quality Requirements), hazard analysis, safety requirements, foreseeable misuse/abuse analysis, product safety testing, product safety review, etc. In almost all the firms interviewed, they seem to have strong quality teams that are delegated with power to hold projects or stop production if there are concerns on product safety. Compared the best performers with the reset, the former has much stronger quality teams with more power than the latter does. However, 91% of firms interviewed have no product safety engineer. The most pervasive practices identified are listed in section B of Table 14.1.

- The quality department head (normally a vice president or director level) is in charge of product safety management and reports to the top leader in the organization. They are normally the ones to make final decision on product safety issue.

This is in line with findings of in the literature (Eads and Reuter 1983; White and Pomponi 2003).

- The firms have product safety specialists whose main focus is on product safety standards, compliance, and hazard analysis. There are 31% of the firms have product safety specialists in engineering department. For other firms, this responsibility is in quality department. They are also in charge of product safety certification/compliance program. However, most of them are not safety engineers by train.

14.4.3 Product Safety Culture

The importance of building a product safety-oriented culture is obvious from the interviews. Almost all the interviewees mentioned that they have positive "PSC" and product safety is No. 1 concern in their firms. Some firms even wrote "product safety first" in their quality policies. As I11 explained, "Product safety is No. 1 in our vein and blood." All the interviewees think product safety oriented culture will help enhance product safety performance. White and Pomponi (2003) also pointed out the importance of building a safety focused culture in the firm to achieve better product safety performance. As I4 explained during the interview, "when you think safety, safety, safety … we all think how to improve safety, how to make product safer…." In general, compared PSC in best performers with other firms, it's obvious that the former has much more strong PSC than the latter. Compared the Chinese firms with the International leaders, the latter has a far better group level PSC in the product development team. Twenty percent of firms have product safety committee. The product safety committee normally is led by the quality chief, with members from R&D, Engineering, and Legal departments. They decide product safety policy, strategy, product safety initiatives, and whether to recall the products from the market if there are safety issues. Some prevalent practices observed on positive PSC are listed in section C of Table 14.1.

14.4.4 NPD Team Organization

It's important to use cross-functional design team to ensure product safety (Hodges et al. 1996). Ninety percent of the firms interviewed use cross-functional team for NPD projects. The percentage of using cross-functional team in NPD is higher than the findings of Griffin (1997) and Cooper et al. (2004a), which reported 84% and 79.3% of firms used cross-functional team in NPD respectively. The NPD teams have regular review (e.g., weekly or monthly) and share failure information in the review. In the team, quality engineers champion hazard analysis, misuse/abuse analysis, and product safety review. Only 9% of firms have full time product safety engineers in engineering group to work on product certification or compliance.

Concurrent engineering is another prevalent practice, meaning all the members participate from the project start to end. However, the level of participating for each function is different at different stage. And the team is accountable for the success or failure of the projects. Ninety-one percent of the interviewees think cross-functional team will help enhance product safety because you have different perspectives, and the product safety review will be more thorough with different specialists participating in the review. Nine percent of the interviewees think cross-functional teams won't affect product safety as different functions normally only focus on their own area. As I4 mentioned, "It (cross-functional team) smoothes the launch, I don't think it will have impact on the safety of the products because different groups focus on different things. For example, manufacturing people are mainly interested in the timing, how to produce it, how to assemble it; purchasing people are mainly interested in communicating with suppliers, starting ordering the material … I really don't think it will have impact on the safety of the product as much as commercial side… to launch it smoother…."

14.4.5 Resources for NPD

Having adequate NPD resources is absolutely important to ensure product safety. This is one area that most firms interviewed are very weak. Only 33% of firms interviewed have adequate resources for NPD. The percentage is a bit lower than the findings of Cooper et al. (2004b). Sixty-seven percent of the firms don't have adequate resources for certain functions. Forty-seven percent of the firms claim they don't have adequate quality engineers and 30% of the firms don't have enough engineering staff in the NPD. Sixty percent interviewees think inadequate resources will affect product safety. As I4 explained, "because when you under staff (quantity and capability), you tend to do thing quicker or have a bit short cut here or there…. We should isolate product development and daily operations otherwise they got suck into daily operations and forget about their priority, because you will fall behind. If you fall behind, you will catch up; when you catch up, you make mistakes; when you make mistakes, you affect product safety performance…" 40% of interviewees think inadequate resources might not affect product safety as the products they develop are mature and there are full tests for the products on product safety at later stage. However, in view that 47% of the firms don't have adequate quality engineers who are in charge of product safety management in the NPD process, most likely product safety performance will be affected.

14.4.6 Training for Product Safety

Training for employees on product safety requirements is crucial to improve product safety (Main and McMurphy 1998; Gookins 2005). Training on product safety for technical staff is an area that most firms don't do well. Although all firms provide some sort of training on product safety standards and regulatory requirements to technical staff, only a few firms have formal safety training. Besides, there are not many firms providing formal training on risk management tools such as Hazard Analysis, FTA, and FMEA etc. This is in line with the research findings from Main and Frantz (1994) that most engineers didn't receive formal training in safety methodologies common to the safety community. Almost all firms interviewed participate in establishing mandatory or voluntary product safety standards in the industry. They have regular meeting to review the standards or any upcoming reversions for the standards. For example, in USA, ASTM (American Society for Testing and Materials) meeting takes place twice a year. Through these meetings, the representatives will relay the updates and provide training to relevant employees within the firms (some even include their suppliers). The firms can also take proactive measures on their products and process before the revised standards are effective. Some firms send employees to attend third party training or bring outside people to conduct in-house training once per year. The most common practices in these firms are summarized in section D of Table 14.1.

14.4.7 NPD Process

The importance and prevalence of formal NPD process have been reported in a number of studies (Cooper and Kleinschmidt 1995, 2007; Griffin 1997; Cooper et al. 2004c). A well-documented formal process for NPD is now the norm (Barczak et al. 2009). In the interviews, we also found all the firms used a formal and flexible NPD process with test/evaluation plan at each stage for new product. The process guides all activities from concept to launch, e.g., Concept Review, Development, Prototype, EP (Engineering Pilot), FEP (Final Engineering Pilot), PP (Production Pilot), RTP (Release to Production). There may be different names, but in terms of the process, all firms have above stages. Depending on how complex the product is, some stages might be combined. The NPD process and common product safety management methodologies applied are presented in Fig. 14.3 – Product safety management process in NPD. The common practices identified (refer to section E of Table 14.1) are:

- A well-documented formal NPD process. All firms interviewed have implemented such a process which incorporates product safety review and acceptance criteria at each stage.
- All firms have well-defined robust product safety requirements, e.g., QR or QP (Qualification Plan). These requirements normally include regulatory requirements in the market and the firm's own internal requirements. The internal requirements are based on previous failure in manufacturing process or market for similar products, the product recall information for the same category, customer feedback, foreseeable misuse analysis, abuse analysis, the engineers own experience, etc. It also includes other requirements such as reliability,

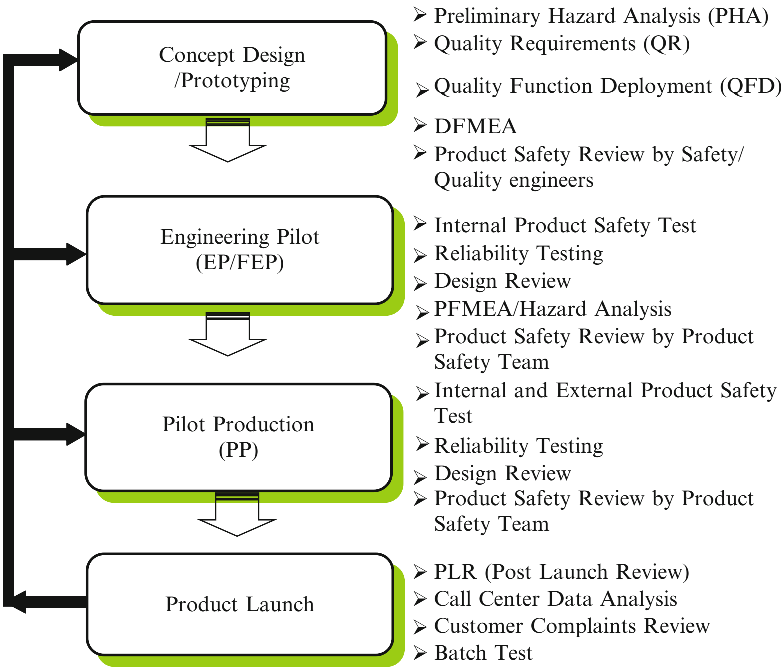


Fig. 14.3 Product safety management process in NPD

durability, functions, etc. How robust the QR is more or less determines how safe the product will be as it captures all safety requirements for the product. All firms mentioned that their requirements are much more stringent than regulatory requirements. Therefore, changes on regulatory requirements have no much influence to their product safety performance. As I4 explained, "…Internal requirements come from products we got back from field, because you see this person didn't use it correctly, how can we make it better to avoid this problem. That is what we gain a lot. That's why I think [Firm XX – ed.] is a very good company in terms of safety because of the returns from field. They weren't returned because they were bad. In fact, they protected the children. Because once a car seat has been involved in car crash, it shouldn't be used again. So instead of them throwing it away, we take it back and give the consumer a new one free of charge. Because we think the value we gain from these seats is very valuable in developing future generation of car seat…. We have a committee from quality and engineering to look at them every week, inspect them…."

- VOC for product safety. Numerous studies cited that VOC is key to the success of NPD (Griffin and Hauser 1993; Cooper et al. 2004c). However, product safety seems to be taken for granted. Normally nothing on product safety will be mentioned in the VOC or customer needs for new projects, unless safety is a feature for the project. As I5 explained, "Marketing is the one to define customer requirements. Only when safety is an added feature to enhance value, it will be mentioned there." I4 also mentioned, "Safety is implied and assumed…. Most of consumers will talk about comfort, easy of use, features, and believe or not, cup holder, although nobody uses the cup holder, it's a very good feature that consumers keep asking for and they don't use it. You must have a cup holder in the booster seats, otherwise the buyers will not buy it. But I'm yet to see a booster seat in a car with some drink in the cup holder." I11 also elaborated, "…There are no voices of customer for safety requirements because they (customers) don't know. That's the issue. They don't know anything on safety regulations, testing for stroller and car seat. Our customers, consumers, the shops, and retailers, they don't have any knowledge of that. They are blind trust related to the brand."

- Customer involvement in NPD. It's obvious from the interview that customer involvement in NPD is a good practice among the firms interviewed. Ninety-two percent of the firms involve customers in their NPD process. I4 explained why customers are not involved in their case, "…because our customers are retailers…. They have no idea, they don't care. You give them the product. If the buyers like it, they buy it. They don't care about anything else." Whether the customer involvement will enhance product safety, it depends what customer you refer to. Sixty-seven percent of interviewees think customer involvement will enhance product safety. Majority of theses interviewees refer customers as big brand owners who know the product categories very well and have been in the industry for many years. For this kind of customers normally they have a lot of experience in the industry and strong technical competency. Their participation in NPD will definitely enhance product safety. Thirty-three percent of interviewees think customer involvement won't enhance product safety. The main reasons are because their customers are retailers, which normally have no knowledge or focus on product safety. As I5 explained, "For retailers, I'm not sure. I don't recall too many incidents that sales and marketing come back to say the customer(retailer) doesn't think it looks safe…. They're more looking at style, price, and competitor, and what margin they can get. Again, I think they are like the consumers, they assume it's going to be safe. You know we are expert, the assumption is it's going to be safe." I11 also elaborated, "No help at all for safety because they (retailers) absolutely (have) no focus on safety, they focus on fit and functions."
- Thorough product safety review and records retention at each NPD stage are a common practice in the leading firm. This is a very important stage and viewed as a requirement by the legal entity (Goodden 2008). Kitzes (1991) recommended firms to create an independent product safety review process. Ninety-three percent of the firms combine product safety review with design review. Only 7% of the firms separate design review and product safety review in order to have more focus on product safety and to prevent any oversight on product safety during the design review. Ninety percent of the firms have quality engineers leading product safety review, the rest are led by product safety specialist in certification/compliance department. One of the risks of combining design review and product safety review is product safety might be overlooked due to many other areas to cover in

the design review. In most firms, product safety review and hazard analysis are purely experienced based, very few firms use systematical methodology recommended by the safety community such as PHA, FTA, FMEA, or HACCP. Product safety review normally covers areas such as (1) compliance with relevant product safety standards and internal QR or checklist, (2) internal or external test results on safety and reliability, (3) hazard analysis and FMEA, (4) warnings required, (5) safety devices, (6) interaction with consumers (children or parents), (7) handling (how the product will be handled by consumers), (8) failure information of similar products in the manufacturing process and market, etc.

- Product safety testing is a crucial stage and a common practice observed in the firms interviewed. Governments and courts expect manufacturers fully test their products before marketing them (Goodden 2008). All firms interviewed have in-house product safety testing capability. This is a major way to check whether the product is safe and can meet the QR. It's also prevalent that all firms have requirements that the product must pass third party test according to relevant mandatory or voluntary product safety standards before releasing it to production even though there is no requirement from governments in some cases. Speaking of the importance of testing, I4 put, "Testing is the most significant practice. In fact, some of the advertising slogans we use in conference are: in order to make it safe for your child, we test it, test it, test it, test it…."
- Foreseeable misuse and abuse analysis. All firms interviewed conduct reasonably foreseeable misuse and abuse analysis for their products. Yet, this is an area that most interviewees think it's very difficult to manage as you might not be able to predict all possible misuse and abuse. Majority of the interviewees cited that most product safety issues observed in the market are because they didn't foresee that the consumers will use or abuse the products that way or in that specific environment. Unfortunately, in the regulatory context in the United States right now, all it takes for the product to be recalled from the market is one case. As I8 explained, "…Misuse evaluation is part of quality responsibility based on experience. Misuse is a big one. I told the development team: I bring up a potential issue, they will say nobody will do that. It takes one person to do that, we're in trouble. So if we develop a product, let's design the product taking into consideration that one person may do that. But that's all it takes now for one person to do something wrong…."
- Field test. Some firms call it home-use test. Forty-one percent of the leading firms conduct field test for new products and all of them think this is a very valuable test which can save huge money and capture some issues you didn't foresee during the development. But most interviewees cited time is the major barrier to do a perfect field test. Sometimes, the field test goes on concurrently with production. Some firms use focus group to observe how the consumers handle and use the products without providing any instructions. As I4 elaborated, "…We do focus groups, go to local hospitals/local schools, show the products to the parents and get their feedback. The best test is with the children seating in it, and observe the children how they seat in it. You watch and see how the people are using the products. You can learn a lot. It's helpful for product safety and quality because

I'm sitting here and designing a product assuming this will be used … because nobody reads manual. Yes, you have it in the manual how to use it, nobody will read it. You have to be self- interactive. And to test how self interactive it is, take it to the field, don't give them the manual and see how they are going to use it because majority of the users will not read the manual."

- Design for safety. The best way to ensure product safety is to design safety into the product, which requires the design engineers familiar with the product safety standards and the safety tools such as hazard analysis, FTA, and FMEA. Unfortunately, as Main and McMurphy (1998) reported most design engineers received very little formal training on these tools, this will limit their capability to ensure product safety. Most of the firms are not using a systematic approach from the safety community to address product safety issues. This seems to conflict with the safety literature. However, we think the main reason is because juvenile products are not as complicated as automobile or other complex equipment. Besides, most of hazards related to these products have been identified and regulated in the national safety standards.
- Design for manufacturability. Most interviewees think it's important to consider process capability during the design, especially for critical to safety process. Ninety-two percent of firms involve major suppliers in their NPD process and 90% of firms involve manufacturing people when the NPD project starts.
- Postlaunch review. Although postlaunch review was identified as a best practice to ensure lessons learnt, there are only around 20% of firms conducting formal postlaunch review (Cooper et al. 2004c; von Zedtwitz 2003). In the firms interviewed, majority of them conduct postlaunch review only when there are pending issues or issues reported during production. However, most of firms do batch test for new products to evaluate product safety and quality. If they find any issues, they will call the team to review the products. In some firms, the team still owns the project 30 days after it's released for production. No firms have formal procedure for postlaunch review. Quality team is the only one who lives through the whole life cycle of the product and enables lessons learnt through analyzing the issues in the manufacturing process and market.
- Supplier involvement in NPD. Supplier involvement in NPD is a prevalent practice in the firms interviewed. Ninety-two percent of the firms involve major suppliers in their NPD process. Ninety-one percent of the interviewees think involving the suppliers in the NPD will enhance product safety. As I8 explained, "…I think our suppliers are expert on the manufacturing of these products. So we depend on our suppliers to give us feedback on making the product better, safer, and make the product design for manufacturability. We're not the expert of manufacturing."
- Risk management tools used in NPD. The use of tools is pretty weak in the NPD. All interviewees think using FMEA will absolutely help improve product safety. However, only 34% of firms use FMEA, 41% of firms use it partially or use it for high risk items such as CRS (Child Restrain System) and medical devices. Twenty-four percent of firms don't use it at all. In the research of Barczak et al. (2009), they reported 48% of the best performing firms use FMEA. It's very rare

to find firms use other tools such as FTA and QFD (Quality Function Deployment). Only 37% of firms do Hazard Analysis. Most interviewees cited that using these tools are very time consuming and the products are not very complicated as reasons for not using them. Another major reason for not using the tools we believe is most of the engineers are not formally trained on these tools. As I2 explained, "Of course in theory the tools will enhance the product safety performance, no doubt about it. But in reality, as mentioned TIME is what we do not have…." This is in line with the findings of Thia et al. (2005) that most of industrialists quoted time as a major factor influencing the use of the NPD tools.

14.5 Conclusion and Future Directions

In this exploratory investigation, we identified 24 leading firms in the global juvenile products industry and conducted 30 in-depth interviews in these firms. Through the analysis of the interviews, it yields a number of conclusions. We uncovered 34 prevalent practices (refer to Table 14.1) which are critical to product safety in the NPD process. Our results show that the leading firms have a strong commitment to product safety from the top management. They foster a product safety first culture in the firm and devote necessary resources to manage product safety proactively. A strong quality team in charge of product safety is prevalent in these firms. Most importantly, the firms have a formal, well-executed NPD process with cross-functional team in charge of product development from concept to launch. Integrating NPD process with hazard analysis and product safety review by quality/safety engineers is critical to safety and was found pervasive in these firms. Most of the firms have much more stringent internal requirements than the regulatory requirements so they think regulatory requirement changes have no virtual impact to their practices or product safety performance. There seems no difference on the NPD practices adopted by Chinese firms and international firms. However, in general the Chinese firms can learn from their international counterparts in terms of commitment to product safety and PSC. On the other hand, it seems Chinese firms are faster to change and adapt new tools such as FMEA than their counterparts.

During the interview, we also observed some issues that most of the leading firms are facing. If the issues below cannot be addressed, the goal to improve product safety further will remain illusive.

1. There is a big gap on product safety management between what the juvenile products industry practises and what the safety community promotes. Most of the methodologies and tools promoted by safety community are not applied by most firms in the juvenile products industry. One of the reasons is lack of formal training for design engineers and quality engineers on safety methodologies. On the other hand, in view of the complexity of juvenile products, some industrialists consider the safety methodologies promoted by the safety community are unnecessary or irrelevant for juvenile products.

2. Inadequate resources, especially for product engineers and quality engineers who are in charge of hazard analysis and safety review. Most of the firms are facing this issue. This is a real obstacle for firms to improve product safety.
3. Most firms don't have product safety engineer position. Quality engineers carry out some responsibilities of safety engineers, however they are not professional safety engineers by train. We strongly believe having a full time professional safety engineer to champion product safety review and hazard analysis will be by far more effective.
4. How safe is safe? Reasonably foreseeable misuse and abuse analysis is the most difficult task facing the quality or safety engineers. As no product can be absolutely safe (Abbott and Tyler 1997), most engineers are struggling with this analysis, especially for engineers who are not well-trained on safety tools.
5. VOC on safety. Product safety is often overlooked by consumers and retailers. When the designers are requested to think about cost, cost, cost … to satisfy the market's requirement on "everyday low price," safety is easily compromised in the trade-off, especially for products that have no regulatory standards. If the retailers and consumers have an "everyday safer" requirement or mentality, we believe the chances are the products will be "everyday safer."
6. Speed or safety? Most firms facing some real issues between speed and safety. Most interviewees cited that they didn't have enough time to do thorough FMEA, hazard analysis, field test etc. because they have to meet the tight project schedule.

This exploratory study has provided new insights to the critical to safety NPD practices. The assumption is the best performing firms have the best practices. Although we cannot statistically generalize the findings due to the limitation of the methodology, it provides us a good understanding on product safety management in the NPD process. We have uncovered some NPD practices which are overlooked in the research of NPD management community, such as hazard analysis, product safety strategy, PSC, etc., which may partially explain why we have so many design related product safety issues in the market. In future research, we can develop a complete survey instrument based on the critical to safety NPD practices identified in this study and conduct large scale quantitative analysis to test the relationships between the practices and product safety performance. Our study also sheds light on how to manage product safety in NPD through a systematic approach. In the managerial perspective, firms can conduct an internal audit based on the practices of the leading firms and perform gap analysis, and then define an improvement plan to address the weak areas. To start with, top management commitment to product safety is No. 1 concern and the management should foster a positive PSC in the company. The firms in juvenile products industry should learn from other industry such as automobile industry, food industry, etc. to manage product safety systematically by applying safety techniques such as PHA, FTA, and FMEA. Last but not least, the six issues mentioned above should be addressed properly. By adapting the best practices identified in this study, firms can build product safety into their NPD process and design safer products.

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