Christopher Palmberg

Sectoral patterns of innovation and competence requirements

– a closer look at low-tech industries

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FOREWORD

This study was carried out as a part of the Research Programme on the Finnish Innovation System financed by Sitra, the Finnish National Fund for Research and Development. The national innovation system is defined as the system of organisations and actors whose interaction shapes the innovativeness of the national economy and society. The main goal of the research programme was to identify the future challenges of the Finnish innovation system. In a rapidly changing techno-economic environment, the Finnish innovation system cannot be expected to repeat its recent successes without continuous and effective development effort.

The research programme included 12 research projects that represented several scientific disciplines: sociology, economics, innovation research, psychology, jurisprudence, etc. The cross-disciplinary approach was chosen to gain many different, but complementary, perspectives on the structure and functioning of the innovation system. The close cooperation of scholars from different disciplines was aimed at creating an innovative research environment for the programme. A particular emphasis was laid on understanding the micro-level innovation processes and innovation networks. The research projects went beyond the traditional organisation- and institution-oriented studies of innovation systems in order to better understand the drivers and context of modern innovation processes. In the changed environment, innovation policies cannot be effective without a deep understanding of these processes and their environment. The results of the whole research programme were synthesised in the programme's final report *Transformation of the Finnish innovation system: A network approach* (Gerd Schienstock and Timo Hämäläinen).

Sitra wants to thank all the researchers, policy makers and distinguished foreign experts that contributed to the success of the research programme. The results of the research programme provide plenty of challenges for further research and future innovation policies.

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PREFACE

The increasing focus on the knowledge-based economy in the policy jargon, and the related emphasis on a set of narrowly defined industries classified as high-tech, unnecessarily takes attention away from the traditional strengths and competence bases of Finnish industries. It is certainly true that the role of such fields as ICT and biotech constitute major opportunities for industrial renewal and growth. However, the traditional industries still account for large shares of employment, production and exports in virtually all industrialized countries – and will continue to do so for quite some time. How the emergence of totally new industries can be fostered is thus not the only key question for the allegedly new economy. It is equally important to support the renewal of existing industries, not least through the adoption of new technologies.

This report relates to a large research project entitled 'The Research Program on the Finnish System of Innovation', commissioned by Sitra. The purpose of this report is to move beyond a simplified view of industrial renewal, where high-tech and R&D intensity are assumed to be the sole drivers for change. The report discusses both general and detailed aspects of innovation and industrial renewal in the traditional or 'low-tech' industries, as exemplified by the wood products and foodstuffs industries.

In order to move beyond aggregate classifications of industries, case studies are essential. Thus I would like to express my thanks to those firms and individuals that provided me with the necessary empirical material, without which this study would not have been possible. I would also like to thank Tarmo Lemola and Staffan Laestadius for their thoughts and comments during the different phases of the project, and my other fellow researchers at the Royal Institute of Technology – Department of Industrial Economics and Management. Finally, I would like to thank my colleagues and external commentators participating in Sitra's research project.

Stockholm, 1.6. 2001
Christopher Palmberg

1 INTRODUCTION

Background

Recently particular emphasis has been placed on issues related to knowledge and learning, whereby the competitiveness of countries is said to depend essentially on the knowledge-creating capacity and learning potential of entrepreneurs, firms and related networks constituting the economy. This emphasis is evident in the terminology adopted by the OECD and various recent policy publications, using such concepts as the knowledge-based or learning economy (Lundvall & Borrás 1997; Archibugi et al. 1999). In Finland, the terminology has also been widely used in policy circles and most recently in the review from the year 2000 of the Science and Technology Policy Council, the main governmental position paper on technology policy.

An unfortunate side effect of the overemphasis on knowledge-intensity and learning processes has been the sometimes one-sided fixation with a narrow set of knowledge-intensive 'high-tech' industries that are assumed to be the main fora for learning, carriers and distributors of knowledge, or sources of economic growth more generally. It is certainly true that some industries are more strategic, dynamic, and faster-growing than others, and thus deserve special attention. Nonetheless, this fixation often overlooks the potential of the more mature, traditional or low-tech industries, despite the fact that these industries still constitute the backbone of the economy in virtually all industrialized countries – and will continue to do so for quite some time.[1] This statement seems all the more relevant amidst the present turmoil of ICT businesses that form the very core of what has been termed the new knowledge-based economy.

Apart from hard evidence of their contributions to growth, as well as mere rhetoric, an additional reason for the fixation with high-tech is that most available indicators are either too blunt or one-dimensional to capture the true diversity and potential of innovation across sectors. Indicators thus tend to overemphasize certain industrial activities, modes and types of innovation, knowledge and learning

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[1] For the sake of clarity, the concept of low-tech industries is hereafter used synonymously with traditional or mature industries throughout the report. The concept is defined and discussed further in the next chapter.

at the expense of others – to overemphasize what you see and neglect what is not statistically visible. Aggregate statistics might be useful for tracing broader changes in the economy. However, ignorance of the true diversity of different industries might be as serious bias that leads the policy discussion off in a direction that is not necessarily compatible the economy's knowledge base and learning potential. Instead, the growth of the economy is a function of all firms and types of innovative activities, no matter whether they are found in the high-tech or the low-tech industries. In fact, there are numerous examples of firms and regions that succeed persistently despite their low shares of R&D expenditures and unfavorable positioning in maturing markets (see e.g. Laestadius 1994; Maskell et al. 1998; Karnoe et al. 1999). Hence, in spite of the attractiveness of high-tech, it is equally important to understand industrial renewal, the origin, nature and potential of innovation in the low-tech industries, outside the alleged core of the knowledge-based economy.

Finland is an interesting country from the viewpoint of high-tech versus low-tech since the industrial structure has undergone rather radical transformation in the 1990s. This is mainly due to the rapid growth of the electronics industry with ICT and Nokia in the forefront. In the most recent aggregate OECD statistics from 1999, this is reflected in the doubling of Finland's share of total exports of high-tech products during the 1990s, mainly at the expense of the relative decline of low-tech products (Figure 1). The largest share is accounted for by the medium high-tech industries, consisting mainly of the machinery and equipment industry and the chemicals industry. When the data for the share of high-tech exports in total exports is updated using national statistics, the figures point towards continued growth to around 20 percent in 1999.

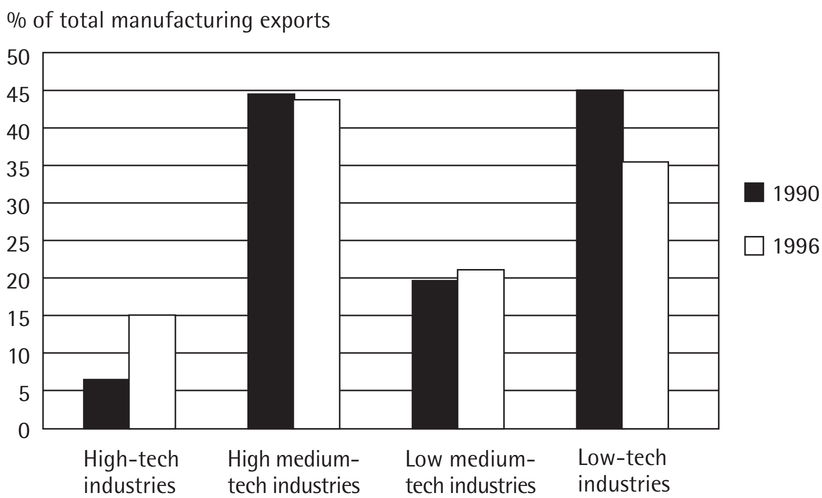

Figure 1. Export shares of different industries according to R&D intensity of total manufacturing exports, 1990 and 1996. (OECD 1999.)

Despite this indisputable positive trend that is also reflected in above average OECD growth rates since the mid 1990s, there is more to it once we get behind the data. In particular, the large share of the telecom giant Nokia in this growth is striking, accounting for roughly 70 percent of the products classified as high-tech in 1998. Furthermore, when we also look at the absolute shares in production and export volumes, and the contribution of different industries to employment, we realize that Finland still relies to a significant extent on the more traditional low-tech industries, such as forestry, metals and traditional engineering (OECD 1999).

A less evident consequence of the growth of the high-tech industries has also been the upgrading of these more traditional industries through the use of new technologies, most notably related to ICT. In a policy framework it thus becomes clear that the continued growth performance will not depend solely on the establishment and further expansion of completely new fields and industries. The renewal of existing industries and an understanding of the conditions and processes that support this renewal are also important.

Research questions and structure of the report

In the light of the discussion above, the over-reaching purpose of this report is to provide a subtler and better understanding of the nature and potential of innovation and industrial renewal in industries characterized as low-tech due to the lesser intensity of their R&D activity. In particular, the paper asks to what degree R&D intensities correctly capture differences in the origin, nature and potential of innovation across sectors, and seeks to move beyond this much used one-dimensional indicator.

Given that R&D intensities only capture one aspect of innovation, the more important follow-up question deals with how knowledge is created and applied in the low-tech industries, and which processes support the emergence of new competencies and businesses and their appropriation through innovation? More generally, it is clear that sectoral classifications of industries conceal the fact that innovation transcends both industrial and institutional borders through networking. Hence, another important question is how the low-tech industries are connected to the broader research infrastructure and to the Finnish system of innovation? Finally, the paper elaborates on these questions in a policy direction by asking which major policy issues face these types of industries?

Methodologically, the report harnesses a combination of descriptive and multivariate statistical analyses of a new and unique database of new products originating from a range of different industries, as well as a set of case studies in two specific competence areas within the wood products and foodstuffs industries.

The statistical analysis is designed to capture broader differences in the nature of innovation across sectors. In the case studies the focus is on the emergence, nature and development of competencies and related new products, enabling qualitative interpretations of the broader statistical analysis from the viewpoint of the low-tech industries.

The paper is structured as follows: Chapter 2 presents and discusses the conceptual and theoretical framework for the empirical analysis that constitutes the core of this report. With the point of departure in the OECD taxonomy of R&D intensities, the broader sectoral concept of technological regime is related to the resource- or competence-based perspectives on the firm. In this way an attempt is made to better account for different competence requirements that might be more or less specific for innovation in the low-tech industries. Chapter 3 discusses in greater detail the nature of the data and methodologies used. Furthermore, the results of the analysis of the survey on new products are presented to illustrate broader similarities and differences in the sectoral patterns of innovation. Chapter 4 describes and interprets the case studies, using some of the terminology discussed in the conceptual and theoretical framework. Chapter 5 concludes the paper with a discussion and policy implications.

2 A CONCEPTUAL AND THEORETICAL FRAMEWORK

The OECD taxonomy of R&D intensities

At the outset, it makes sense to discuss the concept of low-tech industries as well as alternative interpretations that seem useful in this context. It is fair to say that the concept of low-tech and the dichotomous distinction between high-tech and low-tech industries has largely emerged out of taxonomic exercises by the OECD in the mid-1980s to classify industries according to levels of technology (see OECD 1988; Hatzichronoglu 1997). The most commonly used and widespread indicators are based on R&D expenditures collected at the firm level by the national statistical bureaus, aggregated to the sectoral level.

The OECD has established certain threshold levels defining the level of technology industries that account for some 95 percent of R&D in the manufacturing industries. The threshold levels relate to the ratio of R&D expenditures to total sales of the different industries as a weighted average across a sample of 11 OECD member countries (weighted by sector and country). Thus, industries spending more than 4 percent of turnover on R&D are classified as high-tech, those spending between 1.0 and 3.9 percent are classified as high-medium-tech or low-medium-tech. The remaining industries with R&D expenditures below 1 percent of total turnover are classified as low-tech. (Table 1.)

High-tech industries	High-medium-tech industries	Low-medium-tech industries	Low-tech industries
1. Electronics 2. Telecom 3. Pharmaceuticals	4. Instruments 5. Electrical equipment 6. Transport equipment 7. Chemicals 8. Machinery and equipment	9. Petroleum refining 10. Non-metallic minerals 11. Basic metals 12. Metal products, shipbuilding 13. Other manufacturing	14. Foodstuffs 15. Textiles and clothing 16. Forestry-based 17. Printing and publishing

Table 1. Manufacturing industries according to R&D intensity (adopted from Hatzichronologlu 1997).

The OECD taxonomy is clear-cut in the sense that it is based on measurable R&D expenditures and is thus useful for quantitative analysis. Nonetheless, the classification also suffers from some major flaws that should be taken into account in both empirical research and the policy jargon. Despite the fact that the classification is based on weighted averages across sectors and countries, it is obvious that the threshold levels differentiating between high-tech and low-tech are somewhat arbitrary. One major criticism of the classification has concerned the lack of attention given to inter-industrial flows of embodied and disembodied technology and the associated knowledge spillovers (Robertson et al. 2000). It is, for example, the case that the pulp & paper industry is an advanced user of technologies and knowledge originating from the electronics, machinery and chemicals industries, even though it is classified as a low-tech industry due to the low levels of R&D expenditures within the industry (Laestadius 1998).

One way to circumvent the problem associated with inter-industrial technology flows has been to work with the concept of total technology intensity, whereby input-output data is used to incorporate also spillovers. The results of these exercises reshuffle the internal ranking of industries somewhat, but essentially produce a similar broad classification since major performers of R&D are also the major users (the classification in Table 1 is based on total technology intensity)(Hatzichronoglou 1997). However, it is also questionable to what degree input-output analysis correctly captures knowledge flows other than the flow of goods and services.

From the perspective of the present report, the major flaw in the OECD taxonomy is that it is based on a one-sided fixation with R&D intensity as an indicator for levels of technology across industries. In particular, this indicator misleadingly assumes a more or less linear dependence of the levels of technology and related knowledge on R&D intensity (compare to the linear model), thereby ignoring a whole range of other types of knowledge-creating processes — a deficiency also noted by the OECD at the time (OECD 1988; Laestadius 1998). Moreover, R&D intensity is merely an input-indicator that reveals nothing on the differences in the nature and societal effects of innovation output across industries (Baldwin & Gellatly 1999). Thus, this indicator will produce an overly optimistic view of the nature and potential of innovation and industrial renewal in sectors where in-house R&D activities are less important, while overemphasizing the importance of industries where R&D intensity might indeed be central.

A criticism of the fixation on R&D intensity as an indicator of levels of technology or knowledge across industries and sectors can essentially follow two routes. The first route would be more concerned with epistemological issues centering on the definition of what constitutes technology and knowledge, as well as to what degree these are measurable. In particular, Laestadius (1996) notes that the way R&D is defined in the Frascati Manual tends to favor the collection of data of a more scientific nature on knowledge creation at the expense of other types of creative activity of a more synthetic or integrative nature. Such activity is typically related to craftsmanship and engineering rather than the natural sciences. It is based on inductive (trial and error) rather than deductive (theoretically) logic, and largely relies on a tacit and experience-based understanding of the fundamental properties of materials and their combination rather than codification and scientification (compare to Polanyi 1967). The second route, the prevailing one in this paper, is to accept some of the definitional and measurement ambiguities associated with the collection of data on R&D expenditures, and instead focus on understanding better the trade-offs between R&D and other features of innovation in the low-tech industries.

Technological regimes and sectoral patterns of innovation

A discussion on why R&D intensities differ across industries has been at the center of much research within the economics of technological change. Typically, empirical research has focused on the interrelationships between sectoral differences in R&D intensity, as a proxy for innovativeness, and various indicators of firm size and market concentration to capture the structure of different industries. What is more interesting, however, is that the studies have indicated that the structural features of industries reflect some fundamental differences in the characteristics of technologies, competition and markets — or what has been coined technological regimes - rather than the other way around (see especially Nelson & Winter 1977; Dosi 1982, 1988; Malerba & Orsenigo 1993, 1997).

In their original contribution Nelson & Winter (1977) defined a technological regime as "a frontier of achievable capabilities, defined in the relevant economic dimensions, limited by physical, biological, and other constraints, given a broadly defined way of doing things". Apart from the more cognitive considerations surrounding the concept of technological regimes, a few fundamental underlying dimensions have been put forward by, among others, Dosi (1982, 1988) and Malerba & Orsenigo (1993, 1997) that define more precisely the nature, direction and rate of innovation. These dimensions are commonly referred to as the technological opportunities, appropriability and market conditions that characterize different industrial contexts.

In this setting, technological opportunities reflect the ease of innovation for any given amount spent on R&D. In a broader sense, they will be determined by the role played by customers or suppliers as providers of innovative ideas, developments in the sciences and the advancement in equipment and instrumentation originating from other industries, as well as the extent to which firms rely on knowledge inputs from the universities, research institutes or other 'bridging institutions' (Klevorick et al. 1995). Malerba & Orsenigo (1997) also differentiate between levels of opportunity as such, the variety of available technological solutions, and the pervasiveness of technologies. Hence, technological opportunities depend on the origin and rate of scientific and technological advances that feed into particular industries, the level of available opportunities, and the nature of the underlying knowledge bases.

Appropriability conditions concern the fraction of the returns on R&D that the innovator is able to retain and the possibilities of protecting innovations from imitation. Since the responses of innovators and firms to technological opportunities will depend on the degree to which they can appropriate R&D expenditures through innovation, appropriability conditions can either constrain or enable technological opportunities. Technological opportunities and appropriability conditions therefore jointly determine R&D intensities across sectors.

Appropriability conditions are typically discussed at the level of new products and processes, or different lines of businesses. In this context, the importance of patents is acknowledged, alongside secrecy, lead times, and movements downwards along the learning curve ahead of competitors, as well as complementary sales or service efforts (Levin et al. 1987). Other means of appropriation relate to the nature of innovation in terms of continuous incremental versus discrete radical innovation, product complexity, aesthetics or trademarks and design more generally. They might also be identified at the firm level in terms of firm-specific modes of innovation and organization of knowledge-creating activities. Appropriability conditions might simply relate to market domination and barriers to entry, or complementary assets in the form of strong ties to suppliers and customers (Teece 1986; Foss 1997). In a more fundamental sense, appropriability conditions will also depend on the nature of the knowledge base in terms of the degree that knowledge is tacit or codified, and more easily replicated, or specific versus generic due to frequent knowledge spillovers (Malerba & Orsenigo 1997).

Finally, the extent to which technological opportunities can be appropriated through innovation depends on market conditions. These are some combinations of market size and growth, the income elasticity of various products, as well as the levels and changes in relative prices. Dosi (1982) also discusses market conditions in terms of the price of inputs for innovation, which have strong and selective implications in directing technological change along specific trajectories. Nonetheless, while there is agreement that market conditions are important for explaining sectoral patterns of innovation, it is not always clear at what level they exercise their greatest impact. With reference to the introductory discussion, there might exist rapidly expanding 'pockets of demand' in specific product niches, even though the industry as a whole could be classified as a mature one with stagnating demand (Harrigan & Porter 1993).

The concept of technological regimes is interesting in this context for several reasons. First and foremost, one clear analytical advantage stems from the fact that the main forces shaping innovation and associated competence requirements transcend pre-defined industrial borders, thus questioning the use of traditional industrial classifications for analyzing these main forces. An obvious example is the diffusion of such generic technologies as ICT, biotech or new materials, which clearly have pervasive impacts on competence requirements and patterns of innovation in most industries (Freeman & Perez 1988).

Instead of one-dimensional and pre-defined industrial classifications, such as the OECD taxonomy, the concept of technological regimes introduces multi-dimensional interpretations of sectoral differences. In this setting sectoral differences in R&D intensities reflect some fundamental trade-offs between technological opportunities and appropriability conditions that jointly determine firms' incentives to spend on R&D compared to other knowledge-creating activities. For example, Klevorick et al. (1995) suggest that R&D intensity might be a relatively good proxy for different levels of technological opportunities, even though they will not reveal the more precise content and nature of different types of opportunities. However, the more precise content of appropriability and market conditions that are identifiable at different levels of aggregation (the knowledge base generally, the firm and the industry, sector or cluster in question).

Another important insight derivable from the discussion on technological regimes concerns the evolution of industries over time. In a static framework, the fact that R&D intensity differences persist across sectors and industries might indicate that levels of technological opportunities also persist. However, the content and nature of these opportunities might and do change. One viewpoint is derivable from the product or industry life cycle literature (Utterback 1994; Nelson 1994). This line of reasoning points out that in the pre-paradigmatic stages of technological change, technological opportunities tend to be rich and generic as innovators search in various directions and come up with a range of new innovations. As the technology matures and a dominant design emerges, search processes become more stable and predictable, and technological opportunities decline. Thus, as the loci of technological change shifts, the nature of technological opportunities will also change. When these types of dynamics are accounted for, it becomes clear that aggregate sectoral R&D intensities conceal variations in micro-level opportunities facing specific product groups, firms and industrial segments.

Apart from economic arguments, and perhaps more fundamentally, the concept of technological regimes also points to important cognitive dimensions uniting industrial communities in different sectors. This might explain why certain industries are slower to change than others. In this sense, there are conceptual similarities between the concepts of technological regimes, technological paradigms originally coined by Kuhn (1962) and elaborated upon by Dosi (1982,1988), as well as the discussion on thought worlds by Douglas (1986), or communities of practice by Brown & Duguid (1991).

The literature on technological paradigms, thought worlds or communities of practice stresses that behavioral structures and heuristics also exert strong selective pressure on the types of solutions and paths that drive technological change and industrial renewal – the clash of interest between different ways and visions of doing things. For example, as Laestadius (2000) suggests, the pulp & paper industry has been reluctant to harness biotechnology more extensively due the confrontations between the genuinely science-based biotechnology community on the one hand, and the pulp & paper community on the other. Thus it should be acknowledged that there are a range of other deeper factors beyond those of technological opportunities, appropriability and market conditions. These factors also determine the content and trade-offs between different dimensions of regimes that potentially have very large effects on sectoral patterns of innovation and competence requirements.

Resource- and competence-based approaches

The concept of technological regime is useful for identifying certain broader features and trade-offs that explain why R&D intensities, the patterns and organization of innovation differ across industries (for an early empirical contribution along these lines, see Pavitt 1984). However, they do at most only provide some general hints as to what types of competence requirements and strategies different regimes entail for innovating firms (see e.g. Malerba & Orsenigo 1993).

One way to bridge the gap between broader sectoral concepts, such as that of technological regime, and interpretations of different types of competence requirements is through the resource- or competence-based theory of the firm. This theory was pioneered primarily by Penrose (1959) and developed further by others coming from mainstream and evolutionary economics as well as the organizational sciences (see Foss 1997 for a reader). In this context specificities of different types of regimes might be interpretable as different types of 'learning environments' that constrain or expand the repertoires of viable options during innovation.

Moreover, the competence-based view of the firm distances itself from a linear view on innovation that assumes a linear progression from R&D intensities to innovation output in terms of patents and new products. Instead, the progression is from identifying those criteria that make competencies valuable, rare, inimitable and non-substitutable to the firms, irrespective of whether theory or experience, science or technology, high-tech or low-tech creates that value (Eisenhardt & Martin 2001).

It seems useful to discuss value-creating competencies in terms of their salient, albeit interrelated, features (compare to Peteraf 1993 and Foss 1997). The first feature of value-creating competencies is that of heterogeneity. Thus, firms might benefit from specific competencies tied to specific locations or physical resources related to the use of machinery and equipment. Heterogeneity might also prevail due to a range of more intangible issues related to brand names, design, business reputation and strong ties to suppliers or customers. More recently, among others Nonaka & Takeuchi (1995), Spender (1996), Kogut & Zander (1996) and Nahapiet & Ghoshal (1998) have emphasized the role of firm-specific combinative or organizational advantages in the way that firms activate tacit knowledge and organize their knowledge-creating activities to create unique competencies in specific activities.

A second feature of value-creating competencies relates to ex post limits to competition. For competencies to yield durable value, they must be defendable from competitors and imitators. Here a range of issues is discussed that pertain to appropriability conditions in a deeper sense (compare to above). In earlier contributions, Nelson & Winter (1982) introduce the concept of routines to explain why tacit knowledge is appropriated more productively in particular organizational settings than in others. Henderson & Clark (1990) discuss architectural innovation that requires specific types of competencies to combine existing knowledge and technologies in novel ways that are difficult to imitate, as well as modular innovation that changes the core technologies without changing their combination. Prahaland & Hamel (1990) approach the issue through core competencies that are difficult to identify, let alone imitate by competitors. Moreover, Teece et al. (1997) discuss the role of dynamic capabilities as sources for ex post limits to competition. They are a type of second-order competencies to simultaneously exploit existing product lines and explore new ones.

Thirdly, value-creating competencies should be characterized also by ex ante limits to competition. This amounts to processes whereby firms, having once secured accessibility to value-creating competencies, should also retain this access over time and thus sustain heterogeneity also in the downstream factor markets (Peteraf 1993). In particular, Dierickx & Cool (1989) discuss mechanisms whereby value-creating competencies become inaccessible for competitors, or non-tradable on the markets. These mechanisms closely resemble path-dependent phenomena and cumulative learning effects of being in a particular activity or business for a long time. Moreover, they might also relate to the building up of complementary assets, e.g. through secured access to strategic retailers or suppliers, or co-specialized assets through interdependencies between different technologies and competencies for the executing of specific tasks (Teece 1986).

Finally, value-creating competencies should be characterized by imperfect mobility. This underlines the idea that value-creating competencies are tightly intertwined with their organizational setting, they are often highly tacit, non-tradable and firm specific. For example, purely technological competencies related to a saleable patent portfolio or personnel might not be imperfectly mobile, while unique constellations of certain key individuals are not. Moreover, imperfect mobility might relate to such co-specialized competencies that are valuable only in conjunction with one another in specific spatial settings, or otherwise exhibit stickiness in the sense that they cannot be made perfectly mobile without a loss of value-creation.

Towards a synthesis – competence requirements under different regimes

The competence-based view of the firm has been accused of being overly introvert, only catering to firm-internal processes. Nonetheless, many features of value-creating competencies derive more or less directly from the broader 'learning environment' or technological regime in which the firm is active. Thus, a necessary step towards a synthesis of these two strands of literature would be a mapping of the key dimensions of technological regimes that define R&D intensities across sectors - namely technological opportunities and appropriability conditions - against different modes of innovation and associated competence requirements discussed in the previous chapters. Such a simplified mapping is attempted in Figure 2, where the thresholds between strong and weak appropriability or high and low opportunities should be interpreted as fluid (compare to Malerba & Orsenigo 1993).

	High technological opportunities	**Low technological opportunities**
Strong appropriability	• Exploration, emphasis on absorptive capabilities and collaboration in R&D • Value-creating competencies related to organization of collaborative R&D • Radical innovation	• Exploitation, emphasis on transformative capabilities and in-house activities • Value-creating competencies related to organization of production • Modular innovation
Weak appropriability	• Exploration, emphasis on absorptive capabilities and in-house R&D • Value-creating competencies related to the organization of in-house R&D • Architectural innovation	• Exploitation, emphasis on transformative capabilities and in-house activities • Value-creating competencies related to organization of production • Incremental innovation

Figure 2. Trade-offs between technological regimes, competence requirements and nature of innovation.

In the following, Figure 2 is first discussed row-wise and then column-wise, despite the fact that conditions of appropriability and technological opportunities are interrelated. The end-result should nonetheless be the set of trade-offs illustrated in the figure, which should provide a kind of a general conceptual and theoretical framework for confronting and interpreting the empirical material analyzed in the subsequent chapters. In this framework the role of market conditions for shaping competence requirements is omitted due to analytical inconveniences, as discussed above, but should nonetheless be considered especially in the context of the case studies.

Starting off with appropriability conditions, it seems clear that they have an effect on how firms organize their innovative activity as well as the specific competencies that they draw upon when innovating. Thus, in sectors where appropriability is stronger, e.g. due to strong intellectual property rights, it seems reasonable to assume that value-creating competencies are best identified in the ways that firms organize their R&D collaboration with other specialized knowledge sources. Moreover, it might be expected that collaboration with various partners is frequent, due to limited hazards associated with spillovers. More generally, the competence requirements relate to the exploration of new technologies and markets through radical innovation and the development of new competencies, rather than the exploitation of existing ones through incremental innovation (compare to March 1999).

On the other hand, in sectors where appropriability conditions are weaker, e.g. due to generic knowledge bases and the ease of imitation, value-creating competencies are better identifiable in the way that firms organize their in-house R&D activities, or alternatively amongst the range of other non-R&D activities discussed above. These might, for example, relate more to the fine-tuning of production processes, and the recombination of existing competencies through architectural or incremental innovation on the basis of existing product architectures (compare to Henderson & Clark 1990). In this case exploitation through incremental or architectural innovation would overshadow exploration and radical or modular innovation.

If the column relating to levels of technological opportunities is added to the discussion, it could be assumed that higher technological opportunities should also imply a greater need to internalize external knowledge through explicitly developing what Cohen & Levinthal (1990) define as absorptive capabilities. In R&D-intensive science-based sectors a large number of studies indicate the importance played by universities and research organizations for innovation in firms (see e.g. Pavitt 1984 for a general discussion; Orsenigo 1993; Gambardella 1995 for the case of pharmaceuticals). Thus, it is also likely that value-creating competencies are closely related to the organization of R&D both in-house and externally, and to the competencies to combine internal and external knowledge sources (Kogut & Zander 1992). Moreover, Eisenhardt & Martin (2000) suggest that the role of dynamic capabilities might be especially important in these types of 'high-velocity' environments, where change is rapid and unpredictable and the competitive landscape is continuously shifting.

In the case of lower technological opportunities, on the other hand, account should be taken of the fact that opportunities are not solely confined to external knowledge sources, or advances within the sector in question. Instead, firms create opportunities internally or develop idiosyncratic relationships with scientific institutions or gatekeepers that integrate high opportunity technologies into traditional businesses (Allen 1977; Karnoe et al. 1999). This brings to the forefront the need for a more elaborate discussion of absorptive capabilities that do not necessarily depend only on competencies to internalize external opportunities, or on the scale and scope of R&D. In this context Garud & Nayyar (1994) make a useful distinction between absorptive and transformative capabilities, or the capabilities to continually redefine a product portfolio based on existing storehouse technologies and competencies residing within a firm. Moreover, Zahra & George (2000) suggest that the trade-offs between absorptive capabilities and transformative capabilities are contingent in nature. Different types of opportunity and appropriability conditions will determine the relative importance of each of the two types of capabilities.

Garud & Nayyar (1994) coin the concept of transformative capabilities as a complement to Cohen & Levinthal's (1990) notion of absorptive capabilities, with some important normative implications. They highlight the importance of intemporal technology transfer as a key mechanism for capitalizing on existing storehouse technologies residing within a firm. In this sense the attention turns from 'outward-looking absorptive capabilities' to 'inward-looking transformative capabilities', where the choice, maintenance, reactivation and synthesis of available technologies and competencies over time turns into a core competence. This type of competence, where incremental innovation dominates over radical innovation, closely resembles exploitation as defined by March (1999). Thus, it could be expected that transformative capabilities are relatively more important than absorptive capabilities in low opportunity sectors, where in-house activities also could be expected to overshadow R&D collaboration.

3 SECTORAL PATTERNS BY INNOVATION OUTPUT – DESCRIPTIVE AND MULTIVARIATE ANALYSIS

A note on the data used

With the above discussion in mind, it seems fair to assume that the R&D intensity of different sectors captures some salient features of industries in terms of technological regimes or learning environments. More precisely, R&D intensities can be assumed to reflect the levels of technological opportunities, even though the interrelationships between appropriability and market conditions are fuzzier. In the following descriptive analysis of the database on new products, the starting point is thus to identify broader sectoral differences and similarities in the nature of innovation. As proposed by Klevorick et al. (1995), R&D intensities are here taken as proxies for different levels of technological opportunities.[2] The comparison is made by anchoring the new products to different sectors by the principal sector of the innovating firm. For the sake of clarity, only the manufacturing industries will be considered. The service sector is omitted from the analyses due to the fact that R&D intensity is relatively unspecified in these cases (see Patel 2000).

The database consists of some 1 600 innovations commercialized by Finnish firms during 1985–98, of which 1 248 originate from the manufacturing industries. The definitional starting point for the identification of innovations was "a technologically new or significantly enhanced product from the viewpoint of the firm" (Palmberg et al. 1999). The focus on products new to the firms was designed to capture some aspects of the creation or reconfiguration of firms' competencies, while the degree of novelty of the innovation from the market viewpoint was more difficult to evaluate.

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[2] The OECD classification of R&D intensity as applied to Finland by Statistics Finland is used throughout this chapter (see Table 1). More appropriate firm-level data on R&D expenditures are not available due to data confidentiality.

The database on new products is interesting for the present purposes because the starting point has been the identification of the innovation output of firms. Since the data in the database relates directly to the origin, nature and development of individual products, it offers a clear advantage and new viewpoint compared with firm-level surveys such as the Community Innovation Survey (CIS). Moreover, the identification of innovative activity based on the outputs that firms actually produce is intuitively more suitable for incorporating the low-tech industries, where available input-indicators and strict definitions of innovators and non-innovators are less relevant (see e.g. the Frascati and Oslo Manuals). The new products have been identified using literature reviews, the annual reports of large firms and expert opinion. Thereafter the new products have been related to firm registers and innovators within those firms for the purpose of a large survey (for the methodology see Palmberg et al. 1999). The survey was undertaken during 1999 and January-February 2000, and resulted in a response rate of 64 percent.[3]

Before proceeding, some words of caution regarding the database are nonetheless warranted. The focus on new products implies that often secretive process innovations developed in-house for the firm's own use have received less coverage. In a low-tech context, where process technology is often deemed to be especially important, the role of process innovativeness is thus captured indirectly by way of its role in the development of new products. The lesser coverage of in-house process innovation is also compensated by the fact that the focus is on innovation output, whereby firms in the low-tech industries are included even though the products might have been relatively incremental from the viewpoint of the markets (e.g. a new paper quality in the pulp & paper industry). Moreover, the focus is on industrial renewal processes where entry through new products is the more interesting and relevant issue – process innovations increase productivity of existing lines of business but are less important to firms' entry into new business fields.

Another deficiency is that the identification of new products has not been based on statistical sampling, since the theoretical population of 'all' new products is unknown. Instead, the data collection could be described as a designed census with the aim of identifying all possible new products adhering to the specific definition used. The coverage of the database in terms of industries and firm size groups is nonetheless relatively representative of innovative activity in Finnish industry (see Leppälahti 2000; Palmberg et al. 2000). However, for the sake of clarity, only the results for the aggregate industrial categories by R&D intensity are presented. The emphasis is on descriptive analysis, including the Chi-Square test for association when appropriate. The extended tables, including the disaggregated categories, are found in Appendix 1. References to these tables are also made throughout the text.

[3] The construction of the database also relates to the 'Finnish Innovations (Sfinno)' research project financed by the National Technology Agency (Tekes).

Basic characteristics of firms and new products

Structural change and firm composition

The database enables the anchoring of innovation output in time by the year of commercialization, thus providing some indication of structural changes over time in the number of new products (Figure 3).

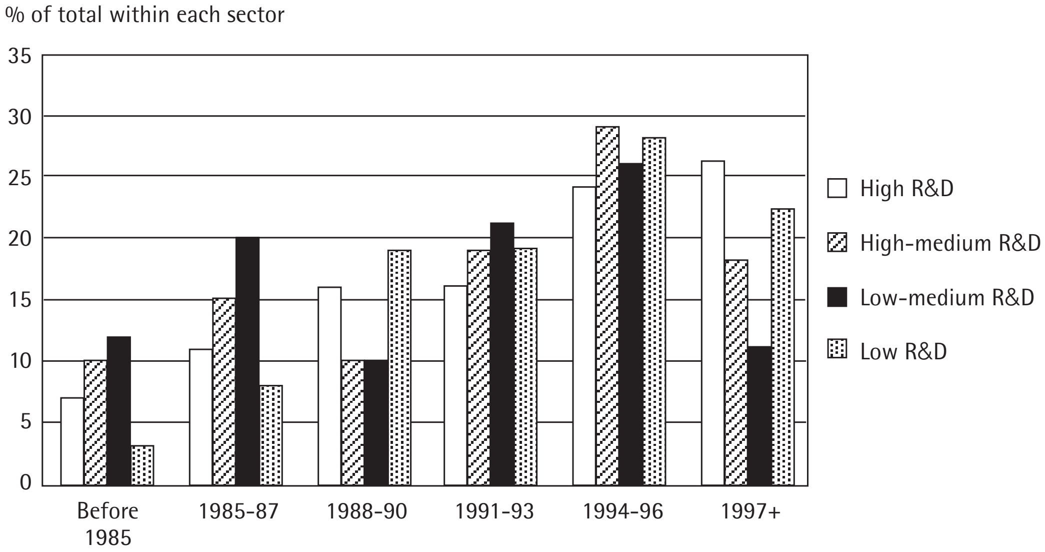


Figure 3. The year of commercialization of new products by R&D intensity (n=888).

Of the total in manufacturing, 37 percent of the new products originate from firms in the low-tech or low-medium tech industries, while 63 percent originate from the high-tech or high-medium tech industries. Looking at changes over time (Figure 2), there is a gradual increase in the share of new products originating from the high-tech. This is coupled with a relative decline in the high-medium tech and low-tech industries.

These structural changes are largely attributable to the emergence of Nokia within telecommunications, as well as the electronics industry more generally, and also reflects changes in aggregate production and trade statistics. Nonetheless, according to the figure the low-tech industries also innovate persistently over time. Based on more disaggregated data, this seems to be true especially in the case of the foodstuffs industry. The fact that the number of new products declines rapidly after 1997 is due to a lag in the identification of new products rather than an indication of decreasing innovativeness.

Another viewpoint is to look at the size and age structures of the firms at the time when the new products entered the markets (Tables 2 and 3 below and in the Appendix). This provides some insights into the renewal processes of different industries in terms of small firms versus large firms, and also into the organization of innovation.

Sector	N	%				
		NA	1–19	20–99	100 –499	500+
All manufacturing	985	26	23	15	12	24
High R&D	115	15	22	7	5	51
High-medium R&D	512	25	28	18	14	15
Low-medium R&D	153	37	18	14	5	27
Low R&D	205	27	14	13	18	29

Table 2. The size structure of innovating firms by R&D intensity.

According to the table there are significant differences across sectors by R&D intensities ($p=0.000$). Overall, larger firms with more than 100 employees dominate in the low-tech industries, while smaller firms with less than 20 employees appear to be more important in the high-tech industries. The share of smaller firms is particularly high in industries such as instruments, electrical and other types of machinery, transport equipment and high-tech electronic components and telecommunications. On the other hand, the share of large firms with over 500 employees is also large in the high-tech industries. In telecommunications this is due to Nokia, while the pharmaceuticals industry is dominated by Orion-Pharma and Leiras-Schering. If small firm size in connection with the introduction of a new product is taken as an indicator of an entrepreneurial regime, the high-medium tech industries are the most dynamic in this respect.

Sector	N	%					
		NA	Other firm	<1 years	2–4 years	5–9 years	10< years
All manufacturing	988	19	16	10	12	16	27
High R&D	115	17	8	7	8	21	40
High-medium R&D	515	18	16	11	14	15	25
Low-medium R&D	153	24	22	8	15	12	20
Low R&D	205	17	17	10	8	17	32

Table 3. The age structure of innovating firms by R&D intensity.

The age of innovating firms is calculated as the difference between the year of establishment of the firm and the year of commercialization of the new product. Thus, it is an alternative proxy for firm dynamics across sectors in terms of new start-ups versus old and established firms. Again, there are significant differences across sectors (p=0.000) even though the results are less conclusive. Somewhat surprisingly, innovating firms in the high-tech industries tend to be older and more established than those in to the low-tech industries. Again, however, this is largely due to the dominance of the few large firms in the electronic components, telecommunications and pharmaceuticals industries. The number of new start-ups or spin-off firms is the highest in the medium-tech industries.

Degree of complexity of new products

The database contains a description of the new products, which has been used to classify them according to product classes. Moreover, the descriptions as well as other available written sources and the Internet have been used to classify the new products according to the degree of complexity embedded in the product artifact, in order to better account for qualitative differences of innovation output across sectors (compare to Kleinknecht et al. 1993 and Santarelli & Piergiovanni 1996). This subjective classification is based on the assumption that the artifactual complexity of the new products in some sense also reflects characteristics of the underlying knowledge base, even though the classification obviously only very roughly captures qualitative dimensions of innovation output and knowledge bases.

Sector	N	%				
		NA	High	High-medium	Low-medium	Low
All manufacturing	985	10	2	38	31	19
High R&D	115	13	3	70	13	1
High-medium R&D	512	8	3	44	36	9
Low-medium R&D	153	14	3	25	42	16
Low R&D	205	11	0	13	20	56

Table 4. The degree of complexity of new products by R&D intensity.

From Table 4 and the Appendix it is clear that R&D intensity differentiates between the degrees of complexity of new products (p=0.001). Industries with a higher R&D intensity also introduce new products of a more complex nature compared to the less R&D-intensive industries. In pharmaceuticals, electronic components and instruments, for example, new products typically involve the integration of several components and subsystems into a functioning whole. In the low-tech industries, new products are typically relatively coherent and simple 'units' (a new type of glue-laminated timber, or a new paper brand). An interesting exception is the forestry-based industries, which score relatively high also in the higher complexity categories. These more complex products are primarily automation, coating and refining systems developed by the pulp & paper conglomerates.

The nature, origin, development and commercialization of new products

Apart from the basic data available on all firms and new products, the survey provides more detailed data on the nature, origin and development of a subset of 569 new products in manufacturing. Since the sectoral coverage of the survey data is hampered by unit non-response, more emphasis has to be given to commenting on broader industrial categories rather than on specific industries with a limited number of observations. In the following I will again only present the results for the aggregate industrial categories by R&D intensity, due to space constraints and clarity. However, reference is made throughout the text to the extended tables in Appendix 1.

Degree of novelty and sectoral linkages

Degree of novelty

The degree of novelty of new products can be assessed from the viewpoints of the firm or the markets. The degree of novelty from the viewpoint of the firm indicates to what degree the innovation process has implied changes in the underlying knowledge base – this was the minimum requirement for a new product to be included in the database. In the survey, a distinction was made between entirely new products, significant and minor changes to the firm's previous activities (Table 5 below and in the Appendix).

Sector	N	Viewpoint of the firm %			Viewpoint of the market %	
		Ent. New	Sign. Change	Minor change	Finnish market	Global markets
All manufacturing	569	61	34	5	24	76
High R&D	45	64	31	4	13	87
High-medium R&D	327	60	35	5	21	79
Low-medium R&D	90	62	36	2	20	80
Low R&D	107	64	29	7	44	56

Table 5. Degree of novelty of new products by R&D intensity.

Apparently, R&D intensity does not differentiate significantly between the degrees of novelty from the viewpoint of the firms (p=0.509). Even though a major part of innovation output in the low-tech industries consists of low complexity 'simple' products, they are nonetheless often quite new compared to the firm's previous competencies. Having said this, it should be noted that the 'new to the firm' viewpoint is tricky in the case of new firms, since these are almost by definition involved in new activities. Therefore, there is a slight bias in favor of the high-tech industries, where the share of the smallest firms with 1—19 employees is relatively higher (for a more detailed analysis of the structure of the database, see Palmberg et al. 2000).

The viewpoint of the market makes the distinction between products new to the Finnish markets and to the global market. This distinction provides some insights into whether the firm is at the technological frontier within the specific product niche. When this viewpoint is taken, R&D intensity does seem to differentiate significantly between industries (p=0.001) (see the two last columns in Table 5). Hence, when moving from the high-tech industries to the low-tech industries, the share of new products regarded as new to the global market decreases steadily, while the share regarded as new merely to the Finnish markets increases correspondingly. Close to 90 percent of the new products in the high-tech industries are regarded as new to the global market, compared to 56 percent in the case of the low-tech industries. When new products that are not exported are excluded from the analysis, the differences remain significant (p=0.001).

Sectoral uses of new products

Another aspect of the nature of the new products is the degree to which they enter other industries as intermediate goods or inputs in production processes. This is relevant in the present context, since many low-tech industries are advanced users of components and machinery from the high-tech industries (compare to the supplier-dominated industries in Pavitt 1984). In the survey, this issue was approached through differentiating between whether or not the new products are used by other firms (Table 6 below). As a follow-up, the respondents were asked to indicate within which industries these firms were using the new products.

One important question is to what extent knowledge-intensive services (KIBS) contribute to innovation in manufacturing and specifically to innovation in the low-tech industries. I have therefore also included new products from the KIBS in the analysis. On the other hand, this does not necessarily capture the rate of diffusion across industries, as less can be said about the different usage and volumes of inter-industrial flows of new products. Rather, it indicates to what degree new products from different sectors find applications in various industries as an indicator of the generic nature of the new products.

Sector	**N**	**%**	
		Used in other industries	**Used by more than five other industries**
All manufacturing	761	57	7
KIBS	141	66	11
High R&D	45	51	9
High-medium R&D	320	53	7
Low-medium R&D	91	59	4
Low R&D	105	56	4

Table 6. Sectoral use of new products by R&D intensity.

In all 57 percent of the new products are used by other firms in various industries. This share is relatively similar across all industries irrespective of R&D intensity. The major exceptions are the electronics, telecommunications and software industries, with shares close to 70 percent. In the second column of the table the benchmark of five user-industries is taken as an indication of the generic use of new products, since there was a clear drop in the share compare to a benchmark set at four industries. This chosen benchmark singles out in particular new products originating from the electronics industry and software as generic compared to the other industries. Otherwise, the results remain relatively indifferent with respect to R&D intensity.

The more significant user-industries of new products are the pulp & paper, chemicals, machinery, electronics, transport equipment and construction industries (table not in the Appendix due to its large size). Moreover, these industries typically receive product inputs from the medium-tech industries and KIBS. The low-tech respectively the high-tech industries are less important providers of input to other industries compared to the medium-tech industries. A closer look, beyond the aggregated categories of the input providing industries, reveals a subtler picture.

Apart from the new products that find applications within the same industry, the forestry-based industries in the low-tech category provide inputs especially to the printing and publishing and construction industries. In the medium- and high-tech industries the significance of inputs originating from the electronics industries is particularly evident, with applications also in most of the low-tech industries. In the case of KIBS it is in particular new products from the software industries that find generic use. Of the low-tech industries, the pulp & paper industry stands out as an important user-industry of KIBS.

Nature of knowledge and innovation processes

The nature of knowledge inputs

In the survey an attempt to capture some aspects of the underlying knowledge base of the new products was made through a question differentiating between a set of broad categories of knowledge-inputs required for the development of the products. A distinction was made between the commercialization of core technology, the development or combination of different components or modules, the development of process technology, the commercialization of service concepts, and other miscellaneous types of knowledge (Table 7). The respondents were asked to pick only one of these alternatives.

Sector	N	%				
		Com. of core technology	Comb. of compo-nents	Dev. of process technology	Com. of service concepts	Other types of know-ledge
All manufacturing	565	34	41	19	2	4
High R&D	45	56	33	2	2	7
High-medium R&D	323	36	46	13	1	4
Low-medium R&D	91	29	41	25	1	4
Low R&D	106	25	27	39	5	4

Table 7. Nature of knowledge inputs required for the development of new products by R&D intensity.

In this case R&D intensity again differentiates significantly across sectors (p=0.000). The commercialization of core technology stands out in the high-tech industries, suggesting that knowledge-creation processes are more focused in these industries. When moving downwards in R&D intensity, the distribution of the importance of different types of knowledge inputs becomes more diverse, suggesting the prevalence of more diverse knowledge bases (this seems somewhat at odds with the assumption above that low-complexity products equal less complex knowledge bases). The importance of the commercialization of core technology diminishes, while the importance of the combination of components or modules and the development of process technology increases.

In the medium-tech industries the combination of components or modules is the dominating type of knowledge input, especially in metal products, shipbuilding and instruments. In the case of low-tech, the development of process technology is the most important type of knowledge input, as reflected in particular in the foodstuffs and forestry-based industries. This is interesting since it suggests that there is a direct link between the development of process technology and the development of new products in these industries. Hence, developments and adjustments of process technology might be a crucial part of the core competence of the firms, rather than something that is typically *a priori* embodied in machinery or equipment of the supplier industries and passively absorbed in the low-tech industries.

The nature of innovation processes

A major part of the survey was devoted to tracing patterns in the origin and nature of collaboration involved in the development of the new products. These issues are obviously interrelated, since collaborative partners provide important inputs for the origin of innovation. Moreover, they presumably also relate to the nature of the knowledge bases underlying different products, albeit on a subtler level than has been possible to capture above.

In the survey the respondents were provided with different alternatives describing the importance assigned to different factors for the origin of the new products (Table 8 below, not in the Appendix) and the importance assigned to different collaborative partners during their development (Table 9 below, not in the Appendix). The scores are on a Likert-scale rating from 0–3, where 0 corresponded to 'no importance' and 3 to 'very important'. In the tables the mean values of the scores are calculated. Since the scale is ordinal rather than interval, the absolute levels are less interesting and the setup is only relevant for comparisons across the industries.

N=553	**Sector**				
	All manu-facturing	**High R&D**	**High-medium R&D**	**Low-medium R&D**	**Low R&D**
Price competition	0.95	0.57	0.90	1.01	1.21
Rival product	0.86	0.77	0.86	0.76	0.95
Market niche	2.28	2.50	2.25	2.22	2.32
Customer demand	2.06	2.20	2.06	2.13	1.95
Public procurement	0.31	0.45	0.29	0.28	0.32
Scientific advances	0.49	1.00	0.44	0.39	0.51
New technologies	0.97	1.11	1.01	0.85	0.88
Research program	0.54	0.50	0.52	0.63	0.51
Environmental factors	0.86	0.18	0.83	1.18	0.99
Regulations, legislation	0.74	0.82	0.70	0.87	0.70
License	0.18	0.50	0.14	0.16	0.17

Table 8. The origin of new products by R&D intensity.

Overall, R&D intensity seems to be quite important for distinguishing between the origins of new products. Customer demand and the observation of market niche are dominating incentives to innovate overall. Nonetheless, customer demand is relatively more important in the high-tech industries than in the low-tech industries. The more significant differences emerge in the case of the intensification of price competition, and the threat posed by rival products. In the low-tech industries competitive pressures related to prices appear to be much more important for the origin of innovation compared to the high-tech industries. The threat of rival products is more pronounced in the foodstuffs and metal products industries, albeit also important in the case of electronics and pharmaceuticals.

These results are interesting since they probably reflect the broader differences in technological regimes of the different industries in terms of the nature and content of technological opportunities. Moreover, they might reflect the role that the development and adjustments of process technology plays in the cost-effective development of new products in these industries – an issue that is worthy of more attention in the case studies. Similarly, environmental issues are more important in the low-tech industries, and especially so in the forestry-based industries, petroleum refining, non-metallic minerals and metals industries. As expected, scientific breakthroughs and new technologies are more important in the high-tech industries, especially in the pharmaceuticals industry. However, also new products in the low-tech foodstuffs and forestry-based industries receive relatively high scores for the sciences compared to the other industries.

N=479	**Sector**				
	All manu-facturing	**High R&D**	**High-medium R&D**	**Low-Medium R&D**	**Low R&D**
Firms of same concern	0.62	0.54	0.52	0.73	0.84
Customers	1.52	1.55	1.63	1.54	1.19
Consultants	0.39	0.37	0.40	0.45	0.34
Subcontractors	0.82	0.76	0.85	0.80	0.81
Universities	0.65	1.12	0.61	0.66	0.53
VTT	0.71	0.31	0.78	0.89	0.53
Other research institutes	0.42	0.82	0.37	0.35	0.44
Competitors	0.26	0.32	0.27	0.19	0.26

Table 9. Collaborative partners during the development of new products by R&D intensity.

When turning to the importance assigned to collaboration and different collaborative partners, less clear similarities and differences emerge. All in all, collaboration is important across all industries irrespective of R&D intensity (compare to Palmberg et al. 2000). Moreover, customers dominate in importance as collaborative partners across all industries, even though they appear to be somewhat more important in the high-tech industries. These results thus also reflect the important role that customers play for the origin of new products. Similarly, the greater reliance on sciences for the origin of new products in the pharmaceuticals industry is reflected in a high score for universities as collaborative partners in the high-tech industries.

More interestingly, however, is the greater role that collaboration with firms in the same concern plays in the low-tech industries compared to the high-tech one's. One straightforward explanation is that firms in the low-tech industries tend to be larger (compare to Table 2). Alternatively, this might reflect other more general features of the organization of innovation in these industries. The importance of the Technical Research Center of Finland (VTT) seems to be greater in the medium-tech industries than in the low-tech and high-tech industries.

Development times

Another interesting possibility of the survey data is to calculate development times for different types of products. Here I will only consider the time taken from the introduction of the basic idea underlying the new product (the year in which the first product development initiative occurred) to commercialization of the product (the year in which the product entered the market on a larger scale) (Table 10).

Sector	**N**	**%**				
		Same year	**1–2 years**	**3–5 years**	**6–9 years**	**10+ years**
All manufacturing	510	6	46	31	12	6
High R&D	37	3	35	27	11	24
High-medium R&D	289	4	47	31	12	6
Low-medium R&D	82	9	38	38	12	4
Low R&D	102	9	56	25	10	1

Table 10. Development times of new products by R&D intensity.

Interestingly, development times are surprisingly short across the board. Slightly over 50 per cent of all new products developed in the manufacturing industries reach the markets in 2 years or less from the time of the basic idea. Across industries R&D intensity does differentiate significantly (p=0.000). There is a relatively clear tendency for products in the low-tech industries to enter the market quicker than in the high-tech industries. This is particularly evident when looking at changes in the shares of new products taking more than 6 years to reach the market from the basic idea. In the case of the high-tech industries it is especially pharmaceuticals that account for the longer development times, while new products in the electronics and telecommunications industries develop significantly quicker.

The results might reflect shorter product life cycles in the low-tech industries than in the high-tech industries, as well as the importance that was assigned to competitive pressure as incentives to innovate. Moreover, shorter development times evidently correlate negatively with the degree of complexity of the products. It is also probable that appropriability conditions are stronger in the high-tech industries. For example, patenting might prolong product life cycles.

Identification of technological opportunity regimes

The above comparison of the nature, origin and development of new products across sectors assumes that R&D intensities reflect differences in the level of technological opportunities. An alternative and more relevant viewpoint progresses 'bottom-up' from shared characteristics of new products, their origin and development, thus abstracting from predefined industrial classifications and R&D intensities. With reference to the conceptual and theoretical discussion above, the survey data is used to identify different types or contents of technological opportunity regimes that appear to feed into different products and reflect the way that the firms organize their knowledge-creating to internalize and appropriate these opportunities. The distribution of thus approximated technological opportunity regimes can be observed across industries as a kind of a robustness test to determine the degree to which R&D intensity and industrial boundaries differentiate between different types and modes of innovation. Nonetheless, the relationships between opportunities, appropriability and market conditions are more difficult to assess, let alone operationalize, with the data at hand.

The setup for this kind of viewpoint is compatible with principal component analysis. Principal component analysis is a multivariate technique used to identify a relatively small number of components that can be used to represent relationships among sets of interrelated variables in a large dataset. The idea is to identify hidden or latent underlying constructs that explain as much as possible of the variance in a dataset, i.e. constructs which are approximated only indirectly through the correlations of various other variables – things that we would like to measure but cannot (Aronsson 1999). In this case, selected variables from the database on new products seem to be well suited for identifying different technological opportunity regimes, based on shared characteristics pertaining to their nature, origin and development. The variables selected for the analysis are presented in Table 11.

Variable	Explanation
Origin of new products	*Likert scale 0-3 by degree of importance*
OPRICE	Intensification of price competition
ORIVAL	Threat posed by rival product
OCUST	Customer demand
OSCIENCE	Scientific breakthrough
OTECH	New technologies
OPRES	Public research or technology program
OENV	Environmental factors
OREGLEG	Regulations, legislation, standards
Collaborative partners	*Likert scale 0-3 by degree of importance*
CCONC	Firm in the same concern
CCUS	Customers
CCONS	Consultants
CSUB	Subcontractors
CUNI	Universities
CVTT	Technical research center of Finland
CREIN	Other research institutes
CCOMP	Competitors
NOV	*Degree of novelty of products on a scale 0-3*

Table 11. Variables selected for the principal component analysis.

Principal component analysis is a mathematical technique that is typically used for reducing and summarizing a larger dataset. Nonetheless, in a more explorative use of the technique it is paramount to motivate, on the basis of previous research and theory, which variables are selected for the analysis (Hair et al. 1992). In this analysis the selected variables are assumed to operationalize different technological opportunity regimes as follows.

The variables OPRICE-OREGLEG are on an ordinal Likert scale 0-3 and capture the origin of innovation. They should reflect some features of the nature and sources of technological opportunities in terms of competition, the role played by the market versus the sciences and new technologies, as well as regulatory issues. For example, OPRICE-ORIVAL probably reflect low levels of technological opportunities due to price competition and imitation, perhaps indicating that products are developed in the maturing phases of technology life cycles, where price considerations and rivalry overshadow Schumpeterian monopoly profits (compare to Utterback 1994). On the other hand, the variables OSCIENCE-OPRES capture the prevalence of high technological opportunities due to the strong link between scientific breakthroughs and new technologies for the origin of new products (compare to science-based sectors in Pavitt 1984).

Another frequent interface during innovation is that with customers as providers of innovative ideas and technological opportunities (compare to von Hippel 1988 or Eliasson 1995). These types of opportunities are captured by OMNICHE-OCUST, i.e. the important role that market niche and customers play for the origin of innovation. Finally, technological opportunities often depend on institutional impediments — regulatory and legislative issues — characterizing the sector or industry in question, as well as standardization and environmental issues. These types of constraining or enabling factors are captured by OENV and OREGLEG, even though their precise effects on innovation are more difficult to assess.

The variables describing the importance assigned to different collaborative partners, CCUS-CCOMP, are likewise on an ordinal Likert scale 0—3. They are taken to reflect some aspects of both the sources and nature of technological opportunities, as well as competence requirements in terms of how internal competencies are combined with external ones. Thus they should correlate with OPRICE-OREGLEG and jointly highlight particular trade-offs between technological opportunities and competence requirements in terms of absorptive capabilities to internalize opportunities (compare to Cohen & Levinthal 1990).

In this setting the variable CCUS captures the importance of collaboration with customers, while CCONS and CSUB capture vertical collaboration with consultancies and subcontractors. The origin of new products from scientific research and new technologies should be associated with collaboration with universities, CUNI, whereas CVTT and CREIN capture collaboration with research organizations inclined to conduct research of the more applied type. The variable CCOMP distinguishes new products that involve horizontal collaboration with competitors. Taken together these variables will also give some indication of the nature of the knowledge base in different sectors and industries more generally, and thus reveal some crude features of related appropriability conditions.

Apart from catering to the levels and content of different types of technological opportunities, the variable describing the degree of novelty of the new products is also interesting and relevant in this setting. It might be interpreted as a rough proxy for different appropriability conditions in terms of the exploitation versus exploration trade-offs at the product level, and for the nature of the underlying competencies. In this case the variable NOV takes ordinal values on a scale from 0—3, distinguishing between products that are incremental both to the firm and the market at one extreme, and products that are radical for both the firm and the markets at the other extreme. Therefore it can be expected that incremental products should be associated with lower technological opportunities, weaker appropriability conditions and the prevalence of exploitation. Radically new products should be associated with higher technological opportunities, stronger appropriability conditions and the prevalence of exploration.

Identifying technological opportunity regimes — principal component analysis

The technique behind principal component analysis essentially computes a set of orthogonal components as a linear combination of those variables that minimize the variance for each component. Thus, each component represents a unique combination of certain correlated variables with different component loadings. The component loadings embody specific and shared characteristics of that component, and the size of the loading reflects its significance (albeit not in a strict statistical sense). As a rule of thumb, component loadings below 0.3 are regarded as insignificant while those above 0.5 are regarded as highly significant. Generally speaking, component loadings around 0.3—0.5 are deemed to be interesting and to reflect that a particular variable receives a strong loading on a factor (Hair et al. 1992). Furthermore, each component explains a share of the cumulative total variance in the dataset. Table 12 presents the attained six principal components.

Variables	'Science -based regime'	'Custom- ized regime'	'Competi- tive regime'	'Regula- tory regime'	'Generic regime'	'Tech- nology oriented'
OPRICE	-0.113		**0.793**	0.117		0.123
ORIVAL	0.113	0.147	**0.803**			
OMNICHE		**0.643**	-0.169			0.221
OCUST		**0.751**	0.151	0.107		
OSCIENCE	**0.646**	0.103				**0.354**
OTECH	0.229					**0.794**
OPRES	**0.336**	-0.202	0.113	**0.343**	0.182	**0.328**
OENV				**0.852**		
OREGLEG		0.141		**0.770**		
CCUS	0.161	**0.658**	0.127		**0.316**	
CCONS	0.154				**0.642**	
CSUB	-0.203	0.101	0.111		**0.482**	**0.511**
CUNI	**0.775**				0.148	
CREIN	**0.705**				**0.320**	
CVTT	0.163	-0.159		0.251	**0.539**	0.203
CCOMP			**0.329**		**0.557**	
NOV	**0.323**		**-0.336**	0.167	-0.108	0.160
Cum. %	11	20	30	39	49	56

Table 12. Results — the attained six principal component loadings (only loadings over 0.1 are acknowledged, significant loadings in bold face) (n=569).

Cumulatively, the principal component analysis explains 56 percent of the total variance in the dataset with several loadings that can be judged as significant. The overall model scores satisfactorily on the Kaiser-Meyer-Olkin measure for sampling adequacy (0.671), which tests whether the partial correlations among variables are sufficiently large. Moreover, the model scores significantly (p=0.000) on Bartlett's test of spericity, rejecting the null-hypothesis that the correlation matrix is a unity matrix. Together these tests confirm that the use of principal component analysis is appropriate in this context. However, it should be noted that the analysis hinges on an assumption commonly made when using survey data, i.e. that the ordinal nature of the variables on a Likert-scale can be interpreted as interval-level data.

The aim of explorative principal component analysis is to give meaningful interpretations of the data-generated components, based on the variables that get high loadings under the respective component. Thus, the first component that explains the largest share of the variance in the dataset is labeled 'Science-based regime'. This type of regime has high loadings on the sciences and new technologies for the origin of new products, indicating high technological opportunity (compared to science-based sector in Pavitt 1984). Moreover, the role of new technologies is evident although this variable has a relatively lower loading. As hypothesized above, firms consequently assign great importance to collaboration with universities and public research institute as a means of internalizing these types of opportunities for innovation. Characterizing innovation output under this regime is a high degree of novelty from both the firm and market viewpoint. The emphasis is on exploration through radical innovation rather than exploitation. This suggests that appropriability conditions are relatively strong, for example due to strong intellectual property rights.

The second component is labeled 'Customized regime' due the high loadings of the variables assigning importance to the role of market niche and customers for the origin of new products. This is coupled with an importance assigned to customers also as collaborative partners. In this case the typical mode of innovation thus seems to involve market stimuli, customers or users as sources of technological opportunities where new product opportunities are customized to specific niches or customer segments. Interestingly, both public research or technology programs and VTT, as a collaborative partner, receive a negative loading. This suggests that technological opportunities are confined to specific applications at the market or customer interface. Accordingly, appropriability conditions might also be strong within these specific applications of new products as established customer relationships might be hard to break.

The third component differs quite markedly from the two previous ones in that competitive factors (price competition and rival products as sources) get high loadings, while new products tend to be incremental as suggested by the negative factor loading for the product novelty variable. Hence, this component is labeled 'Competitive regime'. Under this type of regime, firms organize innovation in collaboration with customers or subcontractors, and especially with competitors that receive a high positive loading. Taken together, these loadings suggest that new products are developed alongside maturing technologies, where price competition and the threat from imitation is pervasive (compare to Utterback 1994). Thus, technological opportunities are probably relatively lower and innovation occurs through exploitation of existing competencies rather than the development of radically new ones (compare to architectural innovation in Henderson & Clark 1990). Collaboration with competitors and the incremental nature of innovation suggest that knowledge spillovers are frequent and appropriability conditions are relatively weak.

The fourth component is labeled 'Regulatory regime' since this component receives a high loading on the importance assigned to environmental issues, regulations and legislation for the origin of new products. Moreover, public research and technology programs are important sources of innovation, and collaboration with VTT is relatively frequent. In this case it is less clear-cut how the results should be interpreted in terms of the content of technological opportunities. Environmental issues, regulations and legislation might direct innovative activity in certain predefined directions, constraining technological opportunities. However, they might also be a source of opportunities through new market openings, paving the way for environmentally friendly products or standardization of uncertain technology. In this case, the product novelty variable scores positively, suggesting that exploration is more pertinent than exploitation.

The fifth component is labeled 'Generic regime'. This type of regime contains high component loadings for most collaborative partners, suggesting that the knowledge base is relatively generic, knowledge spillovers are frequent and technological opportunities are relatively rich. Moreover, research and technology programs for the origin of new products receive a slight positive loading. On the other hand, the generic nature of the knowledge base entailed by this regime also suggests that appropriability conditions may be weaker, an interpretation that is also strengthened by the fact that the product novelty variables receives a negative albeit low loading.

The final sixth component has the highest loading on the importance assigned to new technologies for the origin of new products, alongside collaboration with subcontractors and, to a lesser degree, with VTT. Accordingly, I label this component 'Technology-oriented regime' under the assumption that technological opportunities relate more to the diffusion of technologies than to the science-base per se, and that the internationalization of these opportunities primarily occurs through the application of components and machinery from upstream suppliers or specialized inputs from VTT (this component might bear some resemblance to Pavitt's supplier-oriented industries). On the other hand, the role of scientific breakthroughs, research and technology programs are also noticeable through the high loadings for these variables. The positive but low loading for the product novelty variable suggests that exploration is more relevant than exploitation and also points towards relatively strong appropriability conditions.

Sectoral distribution of technological opportunity regimes — discriminant analysis

The underlying structure of the above-identified principal components, or regimes, gives rise to some hypothesis regarding their sectoral distribution if the point of departure is R&D intensity as a proxy for levels of technological opportunity. In particular, it seems reasonable to expect that the 'Science-based regime' and the 'Generic regime' are typical of the high-tech and high-opportunity industries that draw on scientific breakthroughs, new technologies or generic knowledge bases. Moreover, the 'Competitive regime' fits intuitively well with the characteristics of the low-tech industries as discussed above, since this regime seems to be characterized by maturing technologies and lower technological opportunities. In this type of regime where new products originate in response to price competition and imitation, and tend to develop incrementally. However, the remaining 'Customized', 'Regulatory' and 'Technology-oriented' regimes are trickier to *a priori* assign to specific sectors and industries, and could intuitively coexist in many.

An interesting extension of principal component analysis is to compute standardized component score coefficients for each observation with a mean of 0 and a standard deviation of 1. These can then be aggregated across R&D intensities as an assessment of the degree to which different types of technological opportunity regimes, as defined above, are prevalent in different types of sectors and industries by R&D intensities and levels of opportunities. Moreover, since the principal components are orthogonal and thus statistically independent (avoiding multicollinarity), the principal component score coefficients can be applied in multiple discriminant analysis to provide greater statistical rigor in this assessment. For starters, their sectoral distribution is illustrated descriptively in Figure 4, using the OECD taxonomy of R&D intensities.

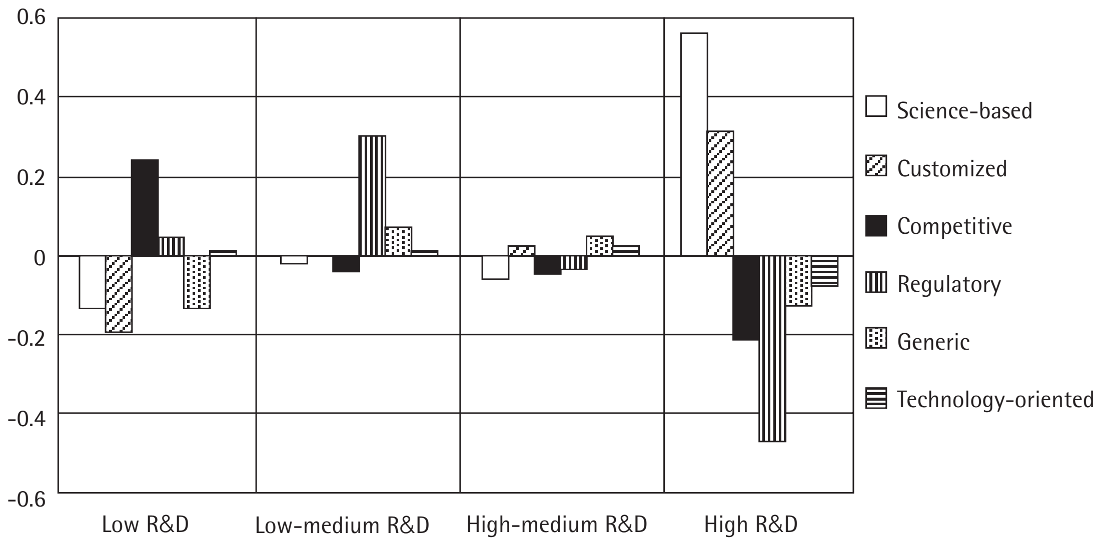


Figure 4. Average principal component scores across aggregate categories of R&D intensity.

There is indeed a relatively clear distinction between the R&D-intensive sectors, where the 'Science-based' and 'Customized' regimes dominate, and the low R&D-intensive industries, where especially the 'Competitive regime' is prevalent alongside the 'Regulatory regime'. In the low-medium R&D-intensive sector, the 'Regulatory regime' dominates alongside the 'Generic regime'. The largest sector by the number of observations — the high-medium R&D-intensive one — is inconclusive in terms of the size of loadings, since they seem to average out and approach zero across the board. One reason might be the inclusion of machinery and equipment in this sector, which contains a range of quite heterogeneous products subject to different types of technological opportunities.

More generally, the less R&D-intensive sectors are characterized by higher scores for those components where the more R&D-intensive industries get lower loadings, and vice versa — thus it seems to be the case that different types of regimes discriminate relatively well between R&D intensities as hypothesized at the outset. Especially interesting is the clear presence of the customized regime in the R&D-intensive sectors, while it scores negatively in all the other ones.

Multiple discriminate analysis involves deriving combinations of independent variables that discriminate best between a priori defined groups. This is achieved by maximizing the between-group variance relative to the within-group variance through the computation of so-called discriminant scores (group means, or centroids) and discriminant functions that achieve this maximization. The interpretation of the functions is similar to that in multiple regression; the discriminant coefficients are comparable to beta coefficients and determine the relative contribution of each independent variable to differences in group means (Hair et al. 1992). In this setting the component score coefficients for each observation enter as the independent variables to explain their contribution to differences of group means across sectors by R&D intensities. The results are presented in Table 13.

Variables	F-ratio	p-value	Discriminant coefficients for function 1	Discriminant coefficients for function 2
'Science-based regime'	10.315	**0.000**	0.734	-0.024
'Customized regime'	2.990	**0.031**	0.384	0.355
'Competitive regime'	3.163	**0.024**	-0.309	-0.593
'Regulatory regime'	6.767	**0.000**	-0.521	0.521
'Generic regime'	1.282	0.280	-0.056	0.502
'Technology-oriented'	0.169	0.917	-0.064	-0.043

Table 13. Results from the multiple discriminant analysis (principal components significant at the 0.05 level in bold face).

The significance tests for the equality of group means confirm that the principal components defined above indeed discriminate between sectors by R&D intensities. The exceptions are the components labeled 'Generic regime' (p=0.280) and 'Technology-oriented regime' (p=0.917). Furthermore, the multiple discriminant analysis generates two statistically significant discriminant functions (p=0.000 for the first, p=0.043 for the second). The first one explains most of the variance of the group means as the differences between the low-tech industries and the rest. Subsequently, the second one explains the differences in the variance of group means of the low-medium R&D-intensive industries and the rest.

A common approach to interpret the relative importance of each independent variable in discriminating between groups is to observe the size and signs of the discriminant coefficients in columns 4 and 5 in Table 13 (the signs of the discriminant coefficients denote the direction of discrimination) (Hair et al. 1992). Following this approach, both the 'Science-based ' and 'Customized' regimes stand out as those with the largest power to discriminate in favor of the high-R&D sectors, while the 'Competitive regime' discriminates the clearest in favor of the low-R&D sectors. Likewise the 'Regulatory' and the 'Generic' regime merely discriminate the low-medium R&D sectors from the rest. The discriminating power of the 'Technology-oriented regime', however, is negligible or unclear. Taken together, these results therefore further confirm the descriptive analysis in Figure 4.

The distribution of average component score coefficients across aggregate sectors by R&D intensities is, of course, a crude point of departure that suppresses some of the strengths of the micro-oriented data at hand. Thus, when moving beyond the aggregate industrial categories, it is expected that the distribution of different technological opportunity regimes is more diverse, particularly concerning those regimes with lower average scores in the broader categories. However, since the dataset suffers from unit non-response in certain industries, and for the sake of clarity, only industries with a reasonable number of observations will be considered. These are the foodstuffs, forestry-based, and metal products industries representing the low-tech industries, and the instruments, electronics, machinery, telecommunications and pharmaceuticals industries representing the high-tech industries. The distribution of different regimes over these industries is presented in Figure 5.

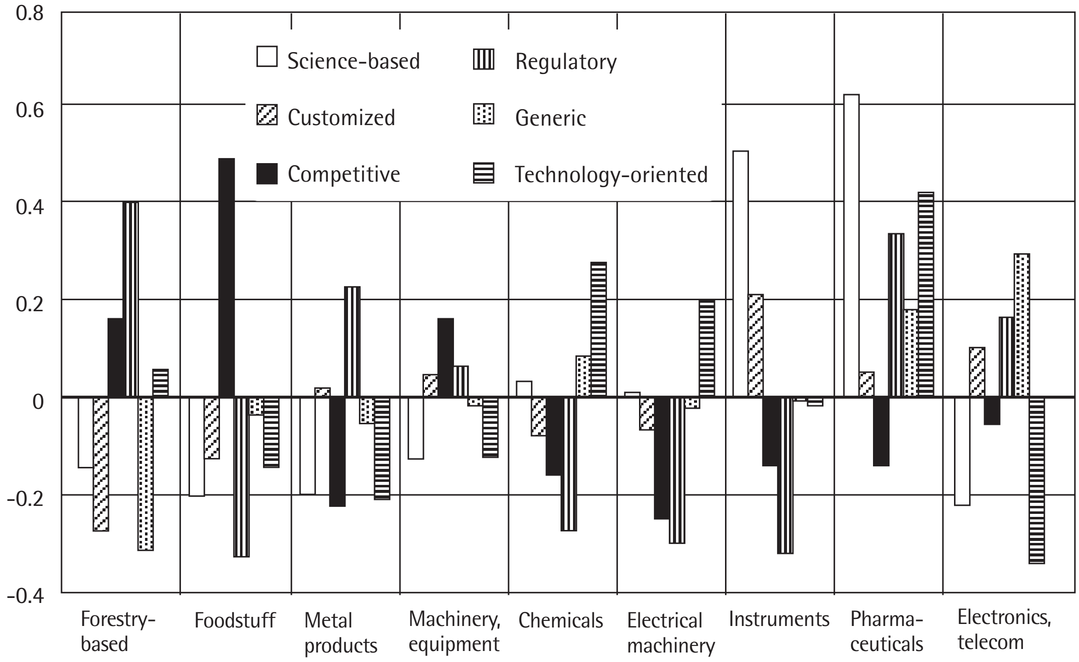


Figure 5. Average principal component scores across industries by R&D-intensity.

In both the forestry and foodstuffs industries the 'Competitive regime' receives a high loading, as expected. This type of regime is much less prevalent in the other industries of higher R&D intensity and gets negative average scores in most of them. The 'Regulatory regime', on the other hand, seems to be quite prevalent in many industries, except the medium R&D-intensive ones. This regime receives high average scores in the forestry-based industries, metal products, machinery and equipment, as well as pharmaceuticals, electronics and telecom. However, the scores are large and negative in chemicals, electrical machinery and instruments. A similar observation is true for the 'Technology-oriented regime', which seems to be scattered about a range of industries. This component scores positively in the forestry-based industries, chemicals, electrical machinery and pharmaceuticals, but significantly negatively in most other ones.

Of the high-R&D industries both the instruments and pharmaceuticals industries receive very high scores for the 'Science-based regime', confirming that especially the pharmaceuticals industry is characterized by a specific pattern compared to the others. In most other industries this regime scores negatively. More generally, the R&D-intensive electronics, telecom and instruments industries and also the pharmaceuticals industry all have in common a combination of the 'Customized regime' coupled with either the 'Science-based' or the 'Generic' regimes. These industries also contain relatively more small firms, confirming that these regimes might be characterized as entrepreneurial with generic knowledge bases and frequent entries. A particularly interesting observation is that the 'Customized regime' appears to be prevalent in the high-R&D industries, but less important in the low-R&D industries. Hence, the market and customer interface appears to be relatively more important in the high-opportunity industries spending more on R&D. This confirms further the insights from the univariate analysis (Tables 8 and 9 above).

In this setting the application of multiple discriminant analysis again confirms that the principal components, or technological opportunity regimes, discriminate between industries by R&D intensity. Once again the exceptions are the 'Generic regime' (p=0.383) and the 'Technology-oriented regime' (p=0.091). However, due to the fact that there now are 9 relatively heterogeneous groups to discriminate amongst, the interpretation of the discriminant functions is trickier and therefore omitted for the sake of space and clarity.

Summing up the statistical analysis

The overall results that emerge in this chapter confirm the relevance of distinguishing industries based on their R&D intensities, as proxies for levels of technological opportunities, from certain viewpoints. In particular, firms tend to be larger in the low-tech industries. New products from the low-tech industries are of the low-complexity type and often develop incrementally from the viewpoint of the markets compared to the high-tech industries, even when acknowledging the fact that the share of products exported is relatively lower. New products from the low-tech industries nonetheless typically require the development of new competencies or the reconfiguration of existing competencies in novel and creative ways – R&D intensities do not differentiate between new products in terms of their novelty from the viewpoint of the commercializing firms.

One important aspect of innovation in the low-tech industries is the application of inputs originating from the high-tech industries and the KIBS. On the other hand, the role of process technology in the low-tech industries seems to warrant close attention, since there appears to be a direct link between the development and adjustment of processes for the introduction of new products to the markets. More generally, the knowledge bases of these industries appear to be more diversified than those of the R&D-intensive industries, given that respondents tend to judge a whole range of different types of knowledge inputs as important. Hence, R&D intensity might indeed only capture a small part of a range of other knowledge-creating activities that might also be central for the development of new products.

New products in the low-tech industries often emerge as a response to price competition or rival products, and the role of environmental issues in their origin is also greater here compared to the high-tech industries. In terms of collaboration, the greater reliance on the sciences and new technologies in the high-tech industries is reflected in the greater importance assigned to collaboration with the universities and research institutes, especially in the case of pharmaceuticals. Otherwise, collaborative patterns appear to be relatively similar irrespective of R&D intensity, although customers receive a higher score in the high-tech industries. Development times are also slightly longer in these industries.

A selected set of variables and correlations between them were also summarized in terms of technological opportunity regimes using principal component analysis in order to abstract from the predefined R&D-intensity sectors and industries. The principal component analysis was elaborated upon in a more confirmatory direction through multiple discriminant analysis, to give greater rigor to the assessment of the degree to which different types of regimes discriminate between different R&D intensities.

In the low-tech industries competitive factors underlying the origin of new products seem to be coupled with weak appropriability conditions, as reflected in a high negative loadings for the degree of novelty of new products, as well as in a high loading for collaboration with competitors. The interpretation is that new products are developed alongside maturing technologies, technological opportunities are relatively lower, and innovation through exploitation of existing competencies dominates over exploration. Alternatively, innovation is subject to regulatory and legislative issues, or determined by environmental factors, where public research and technology programs or VTT provide important input and opportunities to innovation. These types of regimes also coexist with what is coined 'Technology-oriented regime', which define innovation processes that rely on exploration and the diffusion of new technologies, for example related to collaboration with subcontractors. Thus, the low-tech industries are also characterized by 'pockets' of high technological opportunities.

In the high-tech industries, the development of complex, new products draws on the sciences and collaboration with a multitude of different partners. This is interpreted as a reflection of greater technological opportunities, generic knowledge bases and entrepreneurial regimes. Alternatively, new products originate more clearly from market impulses and are developed in collaboration with customers, i.e. the 'Customized regime'. Even though the importance of science-based regimes is as expected in these industries, the high scores for the customized regime compared to the low-tech industries are more surprising. One might also find justification for assuming that it is particularly mass-customization that would be the key for competitiveness in the more traditional and maturing industries. These differences between the high-tech and low-tech industries are further confirmed through the multiple discriminant analysis. Nonetheless, when looking beyond aggregate sectors, it is also clear that the different types of technological opportunity regimes coexist in different industries. These interactions of the different types of regimes might also be important for industrial renewal.

4 DEVELOPING COMPETENCIES IN LOW-TECH INDUSTRIES

From statistical analysis to case studies

The statistical analyses provide interesting insights into broader patterns of innovation across different sectors and industries using product-level data. These insights are important to single out those features of innovation in the low-tech industries that are truly distinct from innovation in the high-tech industries. Nonetheless, it is clear that the applied approximations of technological opportunity regimes only scratch the surface of differences in the subtler type of knowledge-creating activities. The fact that the principal component analysis captures around 56 percent of the total variation in the dataset also points towards missing variables. Thus a proper interpretation of the statistical analyses as well as a deeper understanding of how firms innovate and develop their competencies subject to low-tech regimes requires more detailed case studies.

In this chapter, two sets of case studies are discussed that nicely tie together the conceptual and theoretical framework and the broader insights from the statistical analysis. Since the case studies adhere to a different methodology, their selection criteria are fundamental. The basic idea has been to select specific competence areas in industries that are characterized by low levels of R&D spending, of importance to the Finnish economy, and well represented in the data analyzed in the previous chapter. The term 'competence area' as used here means a set of firms and actors interacting in a specific business field. This resembles closely the definition of technological systems or competence blocs (see e.g. Carlsson et al. 2000), although narrower in scale and scope. Thus the unit of analysis is the outgrowth of a new business field through innovation and a set of key firms interacting in their broader environment within the competence area.

The chosen cases discussed here concern the development of wooden building components in the context of the forestry-based industries, and the use of oats in foodstuffs. These are both emerging competence areas, representing industrial renewal through the development of new products (the products are also included in the product database), competencies and firm growth. The relatively narrow focus of the case studies has been motivated by a desire to narrow down their scope as much as possible, but still facilitate diversity through including different types of competence areas and firms. The case studies are based on some 25 semi-structured interviews and available written material, with particular focus on competence creation within the firms in question and interconnections to the broader regime and system of innovation. The interview structure is attached in Appendix 2.

Wood products and the case of wooden building components

Contextual background

Even though the wood products industry has been overshadowed by the pulp & paper industry and the automation of production has implied a reduction in employment, the contribution of the industry to the Finnish economy is clear. Altogether the forestry-based industries employed close to 60 000 people in 1999. The wood products industry accounted for roughly 25 percent to this total, i.e. some 14 000 people (compared to 24 000 in 1990). The indirect employment effects are quite large due to the fact that the industry sources its harvesting machinery and ICT-based automation from domestic suppliers. Moreover, due to the close link with natural resource endowments and high transportation costs, the industry is of great importance for regional employment and economic infrastructures. In terms of manufacturing exports, the forestry-based industries accounted in 1999 for 29 percent of the total. A breakdown of this share reveals that the main product groups belonged to the pulp & paper industry, while wood products accounted for 21 percent. (Finnish Forest Industries Federation 2000.)

The wood products industry comprises a large number of product and market segments, which in turn differentiates between business strategies of firms. It makes sense to differentiate between different product groups, as this also roughly reflects their degree of value-added and the strategy of firms (Figure 6).

Bulk sawn timber accounts for the largest share of production (43 percent) and this observation is strengthened further if one also looks at the export figures. Sawn timber mainly consists of sawn logs graded according to size and quality,

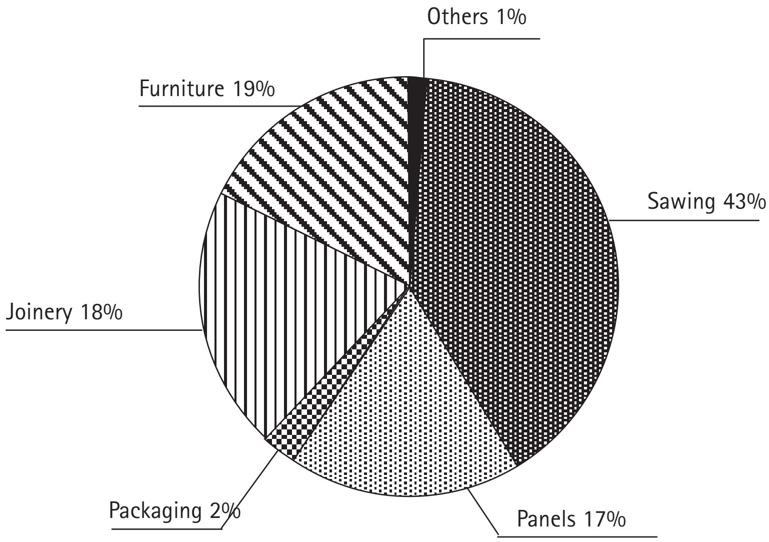


Figure 6. Production of the wood products industry by main product groups in 1998. (Source: Finnish Forest Industries Federation 2000.)

and then dried and debarked for end-use. In the wood panel industry, sawn logs are peeled or chipped down to the core of the log. The thin sheets of veneer or the wood chips are then treated in various ways, dried, graded into different quality categories, and finally glued together to form plywood, particleboard or fiberboard. In the joinery industry, the products range from jointed sawn- or panel-wood timber to complete building systems, such as wooden roof structures or log houses. The furniture industry is yet another segment of relative importance in Finland, which lies closer to the end-consumers. (Finnish Forest Industry Federation 2000, interviews 2000.)

The segmentation of the industry according to more or less specific products and markets provides the major challenge for the firms, and underlies much of the policy discussion in the field as well. Even though the main product groups share obvious synergies downstream in the value-added chain, the selection of raw materials, capital investments and related barriers to entry determine within which segments firms can viably position themselves. Presently, the most dynamic part of the industry consists of medium-sized firms, active in sawn timber, wood panels and joinery to a certain extent. The remaining large share of small firms is more focused in specific niches, primarily within sawn products (specific wood qualities). Nonetheless, despite product segmentation the primary user industry of wood products is the construction industry. Thus, fluctuations in demand depend strongly on the level of construction activity. (interviews 2000.)

The policy discussion has focused on increasing the value-added of wood products through further processing of sawn timber and on ways of increasing the use of wood in construction. Recently, the level of public support to the industry has risen significantly, as reflected also in the rapidly rising share of public funding of firm's R&D. There are also several other schemes and regional initiatives that either seek to complement firms' R&D or increase the use of wood in construction. Furthermore, the public research and science infrastructure has gradually been consolidated primarily through the Otawood group in 1995.

Otawood is a research consortium involving research groups from VTT Building Technology, the Department of Wood Technology, Structural Engineering and Building Physics and Wood Construction at the Helsinki University of Technology. Typically, many projects and larger building sites also involve collaboration with forestry institutes, as well as with designers, engineering offices and public organizations, such as the Finnish National Road Administration and the municipalities. Interdisciplinarity also seems to be the main source of technological opportunities in the industry through the combination of composites, polymers and wood for new uses. This type of interdisciplinarity is particularly evident at the interfaces of the wood products and construction industries, a field in which the two case study firms, Vierumäen Teollisuus and Finnforest, are key players. Nonetheless, Finnforest differs from Vierumäen Teollisuus both in size and scale of operations, as it belongs to a larger forestry conglomerate while Vierumäen Teollisuus is a family business.

A wood products integrate – Vierumäen Teollisuus Oy

Vierumäen Teollisuus is a relatively self-sufficient wood products integrate involved in most activities along the value-added chain, from raw material handling to the conversion of sawn timber into semi-finished components for the construction industry. Treated and precision-cut sawn timber accounts for roughly 60 percent of the company's total sales. Wood products processed to various degrees of value-added make up the remainder. The main processed wood products include glue-laminated beams and bridges, and various impregnated products such as poles, noise barriers, fence posts and landscaping fences. In terms of the main product and market segments discussed above, Vierumäen Teollisuus positions itself in the joinery segment, even though a major share of its revenues still originates from sawn timber.

More than 50 percent of the total output is exported. The single most important foreign market is Western Europe, followed by Asia and the Middle East. In 1999 the firm employed 420 people at four operating locations, all situated in Finland. With a turnover of FIM 640 million, Vierumäen Teollisuus is among the 500 largest firms in Finland; in the wood products industry it is second only to the pulp & paper conglomerates. Moreover, economic figures during the 1990s indicate that the company's performance has been above average compared to the wood products industry as a whole. (Annual Reports 1997–2000).

Diversification from sawn timber to processed wood products

Vierumäen Teollisuus has a de facto monopoly position in Finland in certain product niches related to the use of glue-laminated wood, such as beam structures and bridges. In part, this position has been achieved through substantial investments in the related machinery, but above all through the accumulation of experience in impregnation techniques and the design and construction of glue-laminated components. Moreover, special care has been taken to secure access to high-quality timber in carefully selected sourcing areas. The gradual shift from bulk production of sawn timber to these processed product groups in the 1980s and in the 1990s is also interrelated with public initiatives and increasing interest in the use of wood in construction (interviews 2000).

The firm became involved in impregnated wood products in the mid-1960s. A few years later the first jointing techniques were developed. Through these developments, the product palette gradually diversified towards various impregnated wood products, such as telephone and power poles, bridges and beam structures. The explicit aim was to broaden the product base in the face of rising timber stumpage prices and fluctuating demand for sawn timber. In the late 1970s and early 1980s, the sawmill expanded further through the founding of two new sawmills as well as new wood drying facilities. The mills were fitted with state-of-the-art production lines, enabling customized sawing, drying and sorting. These efforts to automate production and the increasing attention given to the development of various value-added products evidently safeguarded Vierumäen Teollisuus from the wave of mergers and acquisitions, not to mention bankruptcies, which characterized the industry especially during the 1980s.

In 1990 the ownership of the firm changed, although it still remained a family business. Meanwhile, modernization continued with the aim of increasing productivity in bulk sawn timber and setting aside more resources for processed wood products. In the early 1990s a new power plant was installed, enabling the efficient use of wood waste for energy production. Sawing and impregnation capacity was increased further in 1997 through the acquisitions of Innomer (a saw mill) and Helsingin Kyllästyslaitos (an impregnation unit). (Henttinen & Havén 1996.) The most recent investments concern the construction of a new and fully automated factory for glue-laminated wood products. The factory is equipped with machinery mainly from abroad, and will add 70 000 m^3 of gluing capacity per year, mainly for export. Altogether, Vierumäen Teollisuus had a sawing capacity of roughly 550 000 m^3 in 1998 compared to 120 000 m^3 in 1990. Sawn timber is increasingly used for various glue-laminated wood products, in particular as beam structures for public buildings or bridges for rural roads and overpasses, as well as smaller-scale impregnated wood products. In the 1990s the Middle East and Japan became important export markets. Recent major projects in Finland have included the Vihantasalmi bridge, the Pirkka recreation hall and the Sibelius Concert Hall in the city of Lahti. (Fyhr 1999; interviews 2000.)

Innovation through collaborative projects – the example of wooden bridges

The investments in machinery, modernization and the expansion of activities through the founding of new sawn mills are paralleled by a gradual development of competencies within the core areas of the firm, namely the sourcing of wood, impregnation, glue-laminating and jointing techniques. New products have emerged through the recombination of competencies within these fields. The innovativeness of the new products seemingly lies in the overall design and new combinations of these competencies, and the products develop very incrementally. These incremental innovations often depend directly on the development of production methods through process technology, enabling e.g. the sawing of wood in new dimensions, which in turn broadens the product range and customer base. The impulses to innovate are primarily related to customer demand as well as to a need to minimize expenditures and optimize the use of specific types and pre-cut lengths of wood timber for specific products. Moreover, these incremental developments typically involve rather extensive networking with vocational schools, universities or research institutes, as well as engineering offices, designers and public contractors. The in-house R&D resources at Vierumäen Teollisuus are very modest and there is no separate unit coordinating R&D. Rather, product and process development is typically carried out on a project basis with R&D funds being made available when necessary. The related knowledge is highly experience-based and related to certain key individuals within the firm. (interviews 2000.)

The above-discussed characteristics of innovation at Vierumäen Teollisuus are best illustrated through development work related to wooden bridges, a product group which became increasingly important to the firm in the 1990s. As such, the design of wooden bridges has not changed significantly during the last 100 years or so. Nonetheless, Vierumäen Teollisuus has been involved in the development of wooden bridges since the mid-1970s. The first impulses to develop wooden bridges was related to the modernization of sawing machinery and the development of jointing and impregnation techniques, which enabled the sawing and sorting of wood by length and grade, as well as the customized joining and impregnation of glue-laminated wood to fit specific bridge designs. The expansion of the business area was limited by the dominant use of concrete and steel as building materials. Moreover, investment and production costs often exceeded revenues due to the lack of standardized solutions and a larger market.

The use of wood in construction received increasing attention in the late 1980s, as was also reflected in the various promotional schemes and research projects initiated at the time. Wooden bridges was one such area of interest, both at a Nordic and domestic level. In Finland a publicly funded consortium was formed. This consisted of representatives of the glue-lam and wood panel industry (Vierumäen Teollisuus and three other firms), Helsinki University of Technology (the Laboratory of Bridge Engineering), the Finnish Wood Research Center and the Finnish National Road Administration. The aim of this consortium was to investigate new techniques to develop wooden bridges of longer spans, which could compete with the traditional construction materials. The consortium met on several occasions in the early 1990s and was subsequently expanded to the Nordic level through funding from the Nordic Industrial Fund and the National Technology Agency (Tekes). Through these arrangements overlapping research was avoided as research groups from Swedish and Norwegian research institutes complemented the consortium. (interviews 2000.)

Apart from exploratory research that was undertaken during 1994–98, the consortium in Finland was also activated around specific bridge building projects. The consortium developed techniques for the construction of so-called wood-concrete composite bridges and X-connector arch bridges, which provided a cost-effective advantage over previous wooden bridge designs. Apart from the Finnish National Road Administration or municipalities, as the procurers, and Vierumäen Teollisuus, these projects also involved construction contractors and designers. The typical division of labor in these projects has been one where the procurers, designers and Vierumeän Teollisuus produce a basic design. Thereafter the design and prototype is tested and accepted by the Finnish National Road Administration, in collaboration with the research groups at the Helsinki University of Technology and VTT. Hence, although based to a large extent on available techniques from the US and Canada, each new bridge project has added certain incremental innovations to bridge design, enabling e.g. greater spans and bridge widths, as well as new glue-lam joining solutions and designs.

For Vierumäen Teollisuus these innovations have fed back on needs to source specific types of wood timber, the fine-tuning of sawing, impregnation, glue-lamination and jointing techniques, and have added to the stock of experience in these techniques. This kind of competence creation is thus not captured in R&D expenditures. Altogether Vierumäen Teollisuus has delivered 30–60 bridges per year, and smaller pedestrian bridges are also exported. The work within the research consortium culminated in the construction of the Vihantasalmi bridge, the largest wooden bridge in the world with an arch-span of 182 meters. Presently, the third round of the Nordic consortium is underway, with particular focus on the combination of composites and wood for bridge building. (Nordic Timber Council 1999; interviews 2000).

The collaborative mode of innovation described above seems to be quite common during the development of new products at Vierumäen Teollisuus. The new products and innovations – new building components – are often fairly 'simple' and embedded in larger systems, such as in bridges or the roof structures of public buildings. They nonetheless often involve quite complex competence creation processes through extensive on-site collaboration with designers, constructors and university research groups or vocational schools. The main challenge for this kind of collaboration seems to be related to conflicting interests and interdisciplinarity, and to the resistance originating from traditional ways of doing things. The use of wood in construction is still quite uncommon and further developments are often hampered by the lack of standards and regulations. On the other hand, the sustained competitiveness of Vierumäen Teollisuus is to a large extent determined by the close ties that have been established within the network, and also by the accumulated experience that the firm has in running and adjusting machinery for the development of new products.

Finnforest and the development of LVL

Finnforest is an autonomous firm within the Metsäliitto Group, a forestry conglomerate. The group was founded in 1934 as an export franchise of sawn timber. Subsequently, in the late 1940s, the group was reorganized under Metsäliitto Osuuskunta, an association owned by the forest owners with the purpose of securing stumpage prices and promoting wood sales and exports. Since then, the group has expanded significantly and diversified also towards the pulp & paper industry through frequent acquisitions and mergers of smaller sawmills and pulp & paper mills. This expansion and diversification has largely stemmed from the owners' desires to build a strong production capacity when the revenue generated from wood exports and sales to other producers provided lower income prospects (Massau 1993). Today, the Metsäliitto Group consists of two main business areas: wood products, as well as paper, paperboard and pulp. The paper, paperboard and pulp businesses are organized under the Metsä-Serla conglomerate, while the wood products businesses have recently been merged into Finnforest.

Although the sourcing of wood is organized under the conglomerate umbrella of the Metsäliitto Group, Finnforest is a wood product integrate covering the whole value-added chain of wood processing within various segments of the sawn timber and the wood panel industry. Finnforest consists of four main divisions. These divisions are further organized into relatively separate business units. The Sawmilling Division consists of 12 sawmills and accounts for some 40 percent of the total turnover of Finnforest. The Engineered Wood Division accounts for roughly 25 percent of total turnover, and develops and distributes various processed wood products mainly for the construction industries. The Wholesale Division is a leading wholesaler and distributor of plywood and other wood-based panels, accounting for some 22 percent of total turnover. Finally, the Plywood Division accounts for the remaining share and it is the second largest plywood producer in Europe.

Altogether Finnforest employed in 2000 about 4 000 people at 25 production units, the majority of these situated in Finland. The turnover of Finnforest rose throughout the 1990s, mainly due to the profitability of the sawn timber, DIY and LVL businesses. Over 80 percent of the total turnover is exported, mainly to Europe. (Annual Reports 1997–2000.)

The emergence of a new business area – the case of LVL

The competence areas of Finnforest have emerged out of the wood panel businesses of Metsäliitto. The main processed products of Finnforest, i.e. plywood, particleboard, and wooden poles, have remained relatively unchanged during the period of expansion of activities and diversification towards pulp & paper in the 1970s and 1980s. Rather, innovation is characterized by the further processing of available products to a very high finish. This has mainly been achieved through process innovations and the further development of various complementary fields, such as glue-lam and finishing techniques. Finnforest now has a significant market position in Europe, especially in birch and conifer plywood.

An especially expanding product area of Finnforest is laminated veneer lumber (LVL). LVL is made by gluing together peeled softwood veneer to form solid beams and boards for different construction applications, including public and residential buildings, large hall-type structures, warehouses and agricultural buildings, as well as recently for concert halls and wooden bridges. LVL is durable, lightweight and precision-machined, and thus superior to traditional sawn timber. Moreover, the high degree of finishing and esthetically pleasing appearance of LVL also make it a competitor to glue-laminated timber. Recently, an explicit aim has been to build up a system of alliances with entrepreneurial firms in the industry, thereby broadening the product palette towards new areas and business solutions such as heat-treated wood and the implementation of e-commerce. (Mäkynen 1999; Annual Reports 1997—2000.)

The strong position that Finnforest presently has in Europe with this product is a result of continuous product development and organizational innovations dating back to the mid-1970s. During this period the product has not undergone any radical changes. Instead, product development has been characterized by incremental innovations in the underlying structures of the material, in jointing and glue-lam techniques, in the visual appearance of the product. These incremental changes have, in turn, expanded the usage of LVL towards a range of new and specific applications in construction. Another significant source of competitiveness within this product group is related to branding and standardization of the product to different construction norms and customer segments. These efforts are reflected in extensive networking with research institutes, universities, retailers and customers both in Finland and abroad. (Kairi 1999; interviews 2000.)

The history of LVL and the associated business area dates back to the early 1970s when the Metsäliitto Group actively looked for new processed products to increase the value-added of timber in the face of rising stumpage prices. The idea behind LVL as such was not new. In the US, the Forest Products Laboratory had published articles on related techniques, and production of this type of product had already commenced a few years earlier by Truss Joist Co on the West Coast. These experiences and publications from the US led to the initiation of a research project at the corporate R&D unit of Metsäliitto in collaboration with the forest product laboratories at the VTT and Helsinki University of Technology.

During early phases of development the main concerns related to standardization and safety regulations regarding the durability of the material. LVL was a completely new concept in construction and one of the first processed wooden building components on the Finnish market. Meanwhile development work related to production methods was initiated, and the first pilot production line was set up in

1975. In the same year the first product approvals were granted for marketing the product in Finland. Close collaboration with both VTT and Helsinki University of Technology continued throughout the 1970s and 1980s, and resulted in several dissertations and publications.

During the pilot-phase and collaboration with VTT and Helsinki University of Technology, the LVL concept was revised several times. A production technique that allowed for continuous sawing and glue-lamination was developed and patented, and this made the product more suitable for specific applications in construction. The raw material was also changed from birch to conifer, which has higher durability values. (Rakennustaito 1995.) More emphasis was given to marketing and exports, since the product had to pass through various tests and modifications for acceptance as a new construction material in various export markets. Thus, during the 1980s and 1990s, technological innovativeness had to be coupled closely with various organizational arrangements, branding, collaborative venturing and strategic alliances on different markets.

Incremental innovation coupled with strategic partnerships and customization

Technologically, the further development of LVL as a business area has primarily related to investments in machinery and the fine-tuning and adjustment of production methods and related machinery in order to broaden the application areas from simple beam structures towards more complex building components and systems.

During 1979—81, investments were made in machinery and equipment in close collaboration with a supplier firm. The development team at Finnforest contributed with the patented solutions and related know-how of continuous sawing and glue-lamination, while the supplier provided the hardware machinery (interviews 2000). In 1986 a second production line was constructed, doubling the LVL production capacity. Recently, Finnforest has invested in a third and fourth production line in Finland and the existing lines have been modernized with state-of-the-art technologies. By 1999 the LVL production capacity had risen to approximately 100 000 m^3 compared to 10 000 m^3 in 1985. In 2001 the fourth production line will add 70 000 m^3 of additional capacity. Meanwhile the share of exports in total turnover has risen from 20 percent to 80 percent during the same period. (Kairi 1999; Annual Report 2000.)

Alongside investments in machinery, the development and adjustment of production methods and the broadening of application areas, new collaborative partners have entered the network. During the 1990s LVL evolved in a succession of phases, whereby the visual appearance of LVL has been enhanced. The latest phase relates to the application of machine-vision for sorting wood qualities right down to the individual softwood veneers. To a large part, the incremental developments of the product has occurred in close collaboration with research groups at Helsinki University of Technology and VTT in connection to the Otawood research consortium. This collaboration has evolved around the same key persons involved with LVL right from the start at Finnforest. Finnforest has also participated with LVL in various public construction projects, such as the Sibelius Concert Hall, other public buildings, and more recently also wooden bridges. During 2000 the focus has increasingly been on developing turn-key building systems and solutions for customers within the construction industry (Annual Report 2000).

The present strong position of LVL on European markets stems largely from the fact that Finnforest has managed to develop a technological advantage in terms of process technology and the high degree of finish of the product, which in turn has broadened the applicability of LVL to various construction sites. Nonetheless, the strong position on foreign markets is also largely attributable to successful partnerships and the creation of a strong brand name.

The fact the LVL represents a new concept and building material, as well as a competitor to traditional materials, such as concrete and steel, has implied that each new market opening has been preceded by an extensive partnership with various foreign research institutes and sub-contractors. Moreover, the business idea has been to forge partnerships with local foreign subcontractors, whereby Finnforest essentially sells know-how and technical services related to the further processing and application of LVL on different construction sites. For this purpose an extensive repertoire of standardized and customized applications of LVL have been developed to cater to various national construction norms, regulations and practices. While these types of organizational arrangements evidently explain the export success of LVL, they have also constituted a significant challenge during the various stages of the product's development. In sum, the development has been directly coupled with significant efforts to combine technological innovativeness with standardization and customization of the product, and also with new business models based on partnership.

The case of foodstuffs and the use of oats in foods

Contextual background

During the 1960s and 1970s the Finnish foodstuffs industry diversified and upgraded itself technologically, mainly through the purchase of machinery and equipment from abroad. In the 1980s and 1990s the industry underwent a wave of rationalization, mergers, acquisitions and internationalization as a result of extensive investments, increasing productivity and competition due to Finnish membership to the EU. Today, it is highly capital-intensive and concentrated especially in the product segments that are more extensively involved in exports. (Finnish Food and Drink Industries Federation 2000.)

The foodstuffs industry is significant in the Finnish economy in terms of production volumes, employment and its direct linkages to agricultural production and other primary industries upstream, and to the service sectors downstream. Moreover, the industry is an important user of packaging technologies and products, chemicals to a certain degree, and ICT and automation for production and logistics. In 1998 the industry employed directly 41 000 people. The indirect employment effects of the industry are significantly larges if all upstream and downstream linkages are taken into account.

The foodstuffs industry consists of relatively clearly defined industrial segments. These segments differ primarily in terms of the raw materials base, even though the core food processing technologies are more or less generic. (Salo et al. 1998; interviews 2000.) (Figure 7)

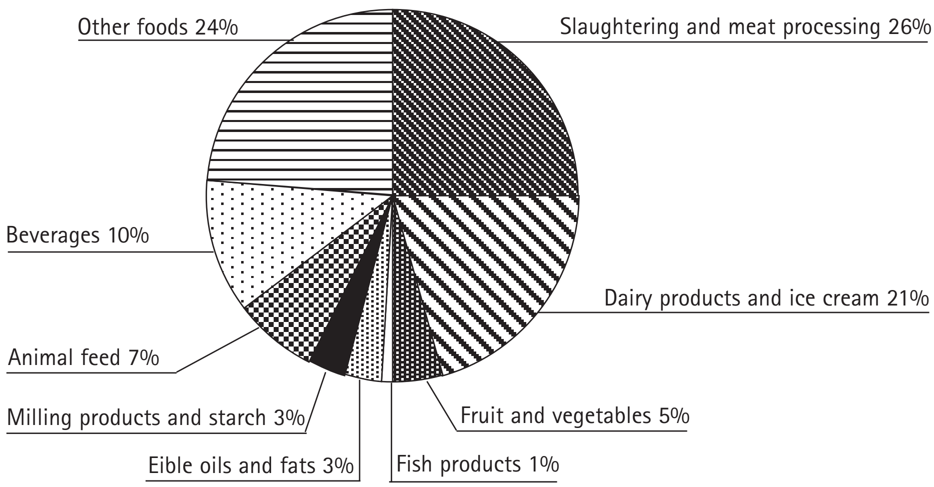


Figure 7. Main industrial segments of the foodstuffs industry according to gross value of production in 1998. (Source: Finnish Food and Drink Industries Federation 2000.)

Slaughtering and meat processing constitutes the largest share of the total production of the foodstuffs industry (26 percent), followed by dairy products (21 percent). The slaughtering and meat processing industries are dominated by HK Ruokatalo and Atria. Valio Oy dominates in dairy products and is also the flagship of the Finnish foodstuffs industry. Likewise the remaining industries are by and large also dominated by a couple of larger firms, such as the Raisio Group (margarine, milling and chemicals), Leaf Oy and the Finnish-Swedish venture Fazer-Cloetta (confectionery), Hartwall and Sinebrychoff (beverages).

Advances in different technologies find applications more or less simultaneously in the various industrial segments of the foodstuffs industry. Presently, technological opportunities related to new advances in biotechnology appear to be particularly rich and may lead to further improvements in productivity, an increase in the ability to switch between different raw materials, and more efficient control over variations in the quality of raw materials. Nonetheless, the markets are sensitive about biotechnologically modified foodstuffs, thus minimizing the return to R&D that a firm might expect in these new fields. At present, more commercially viable paths are opening in the field of functional foodstuffs, drawing on research in the fields of nutrition and health. Research into the use of new materials, such as polysaccharides and synthetic materials, is leading to new raw materials in packaging, thereby enhancing salability, preservation, and biodegradability. The role of new IT-based intelligent control systems is also becoming increasingly important. (Salo et al. 1998; interviews 2000.)

The grain-processing industry — the focus of the case studies — is traditionally sheltered and largely home-market-oriented owing to high transportation costs and compressed world market prices. It is also highly regulated and dependent on the quality that grain yields, which in turn varies with weather conditions. Today the grain-processing industry is dominated by a couple of large and highly efficient mills, most notably Melia Oy, Oulun Mylly, Tuottajan Mylly and Helsingin Mylly. The remaining ones are much smaller and typically tied up to close partnerships with local bakeries. (Heino 1988; interviews 2000.)

Of the main grain types, the Finnish climate offers a comparative advantaged for oats and rye. These grain types have been cultivated more extensively in Finland than compared to other countries. Despite the relatively marginal export potential of oats- and rye-based products, there has recently been a revival in the use of especially oats in foodstuffs due to the recognition of its health benefits. This is largely due to research undertaken by research groups at the Department of Crop Production and the Department of Food Technology at the University of Helsinki, the Agricultural Research Center of Finland and VTT during the 1980s and 1990s. The research centered on the fractioning of oat bran either as a dry milling process or a wet milling processes with the purpose of increasing the level of beta glucan in the bran, the nutritional part of the oat grain with proven favorable effects on cholesterol levels and the digestive system.

More recently, there has been increasing interest in research on fermentation processes in connection with oats and the combination of probiotic bacteria for the development of new products. These activities are also manifested in the National Grain Development program commissioned by the Ministry of Agriculture and Forestry, which includes several product-specific programs on the processing of oats. The National Technology Agency (Tekes) has also included the processing of oats as a sub-theme in its Innovation in Foods program 1997–2000. (interviews 2000.)

Melia Oy and the development of oats-based products

Melia belongs to the diversified foodstuffs conglomerate Raisio. The Chemical Division of Raisio accounts for 39 percent of turnover, followed by the Grain Division (29 percent), and the Margarine Division (23 percent). In 1999 the Raisio Group had a turnover of FIM 4 536 million and an average personnel of 2 897. Exports account for some 50 percent of the group's turnover. On average, Raisio spends some 2 percent of its turnover on R&D, which is coordinated at group level by the newly established Technology Development Board, but undertaken at the level of the divisions. Most of the R&D activities are concentrated in the Chemical Division. (Annual Reports 1997–2000.)

The emergence of functional oats as a new business area

Raisio's Grain Division comprises the Animal Feeds and Milling subdivision Melia Oy. Melia was founded in 1990 through a merger of the wheat mills as well as Vaasan Mylly and Osuustoiminnan Myllyteollisuus Meira. These mergers were the result of increasing competition and overcapacity problems, and they restructured the whole Finnish grain-processing industry. Presently, Melia has a market share of 50–70 percent in most of the product areas and a strong brand name. Melia has production plants at three locations in Finland. Nonetheless, the ownership structure is split between Raisio with 75 percent and the Swedish grain conglomerate Serialia with 25 percent. Serialia has acquired concessionary rights to market certain products of Melia, while Melia markets Serialia's cereals on the Finnish market. Serialia and Melia also collaborate in product development to a certain extent.

The bulk of the turnover originates from the milling of various unprocessed grains, most notably wheat. Approximately one third of the turnover originates from the further processed grain products, such as various flakes and cereals, and pastas. Traditionally, wheat has been the most important grain type, but starting from the 1970s the use of oats has received increasing attention. Thereafter Melia has developed unique and specialized competencies in the fractioning of oats through dry-milling processes and its further processing into foodstuffs (Raisio Yhtymä 2000; Heino 1989).

Melia's product range is characterized by relative stability over time. The new products that have been introduced have typically been based on a novel combination and incremental change of existing oats bran components and cereals that increase the value-added of the existing products. Thus, apart from the dominant market position and strong brand name that Melia has, the competitiveness also depends on coupling production methods and the market interface through the development of new products. These knowledge creation processes have nonetheless also been subject to discontinuities, especially in the 1980s and 1990s through the increasing attention given to functional foodstuffs and nutritional issues. Some of the required competencies have resided outside the firm. Hence Melia has also participated relatively actively in the various public programs commissioned by Tekes and the Ministry of Agriculture and Forestry. (interviews 2000.)

The further processing of grain into various value-added foodstuffs has to be balanced against the fact that bulk production constitutes the main source of revenue in the industry. In the case of Melia, the broadening of the product range from wheat-based towards oats-based products and other grain types in the 1970s and early 1980s coincided with increasing awareness of the good nutritional and dietary properties of oats. This awareness fed on the public debate in Finland as well as new clinical research in the US. It created the necessary incentive to diversify the raw-materials base of Melia alongside the modernization of the wheat mills that also was undertaken at the time.

The processing of oats required the installation of new production lines and related new competencies, due to the specific biochemical structure of oat. Hence, in 1978 new machinery was purchased from a German supplier. Significant in-house efforts were made to adjust production in accordance with the specific properties of oats as a raw material. The first oats-based cereals appeared on the market in 1979 and had carved out a significant market position already a year later. Meanwhile the production methods had also been modified significantly through computerization and better quality control. The milling capacity was increased from 250 000 kilos to 370 000 kilos daily. (Heino 1988; Alho-Lehto 2000.)

The first oat-based products were still based on traditional fractioning and dry-milling techniques that had also been harnessed for wheat milling, primarily in response the boom in the consumption of oats following clinical research in the US. However, Melia also participated in a collaborative Nordic project commissioned by the Nordic Industrial Fund and Tekes. This project was concerned with modifying and developing new wet-milling techniques to enrich further the protein and beta-glucan values of the oat bran. During the 1980s, the project included research groups from the other Nordic countries, VTT, the University of Helsinki, and several industrial partners.

Although Melia subsequently developed their dry-milling process mostly in-house, the outgrowth of a community of researchers focusing on the processing of oats provided a basis for further opportunities. This research community compensated for the limited in-house capabilities that characterized the industrial partners. (interviews 2000.) Hence, in late 1980s a modified and enriched cereals based on oats bran was introduced to the market. These products entered the markets at a time when the popularity of oats-based products was rising significantly, and Melia could extend production to exports as well. Melia also acquired the cereal and brand name Elovena through the merger with Vaasan Mylly. Other significant new products have been oats-based pasta, introduced in 1995, and Elovena+, introduced in 1999. Both of these contain innovative features over previous products and represent functional foodstuffs due to higher levels of beta-glucan in the oats bran. Furthermore, the introduction of these products was also well timed since the Federal Drug Agency in the US, the major regulatory authority in the field of clinical research, had recently approved the use of official health claims in the marketing of oats-based products. (Alho-Lehto 2000.)

Reacting to market opportunities in a production-intensive environment

Melia's oats-based business is an interesting case of the creation of value-added products in the context of a very traditional and production-intensive industrial segment of the foodstuffs industry. Apart from the collaborative projects that Melia has continued to participate in, most of the competencies related to the dry-milling process of oats has been developed in-house. Presently, the dry-milling process is being fine-tuned to extract relatively high beta-glucan values in the oats bran compared to the more expensive wet-milling process. (interviews 2000.) In addition, the purchase of the raw material is coordinated at the group level through the 'Quality Grain' system. This IT-based system enables Raisio's Grain Division to purchase specific grain qualities for specific product groups in close collaboration with the farmers. In this way it becomes possible to control and monitor the quality of the raw material down to the level of individual grain brans, before the raw material enters production. (Annual reports 1997—2000.)

The nature of innovation in Melia thus typically feeds on certain core technologies as a response to trends in the marketplace. Melia's share of the total R&D budget of Raisio is small and Melia does not organize research in a formal manner. Rather, product development occurs at the intersections between marketing and production, in close association with modifications of production methods through the development of process technology. The knowledge of how to operate and modify machinery and equipment for the development of new products is highly experience-based. Furthermore, the integration of externally sourced clinical or analytical research depends on the professional expertise of a couple of people with a long employment history at Raisio.

However, despite the fact that increasing awareness of the nutritional and dietary valuable properties of oats seems to provide new opportunities in the field of functional foodstuffs, the major challenge is that oats is still a marginal grain type with limited demand abroad. Oats-based products face competition from the processing of other raw materials with similar nutritional and dietary features. The further development of the business area is also determined by the further segmentation of the market and sensitive trends, some of which are difficult to detect and react to due to short product life cycles and rigidities associated with high fixed investments. In addition, further regulatory reform in connection with health-related marketing claims is an important prerequisite for functional foodstuffs to be given accepted status as a new category somewhere between conventional foodstuffs and pharmaceuticals.

Yosa and the case of Bioferme Oy

The above-discussed Nordic research consortium as well as increasing recognition of the health benefits of oats created the necessary critical mass for industrial application. Nonetheless, it seems that the practical scaling of activities from laboratory conditions to industrial production has been hampered by the reluctance of the foodstuffs industry to incorporate new process technologies and products into existing business lines.

The wet-milling processes that became the prime interest of the above mentioned consortium during the late 1980s and early 1990s has proven too expensive compared to the dry-milling process that is the conventional one in the grain-processing industry. Moreover, the lack of in-house research resources in the industry has evidently created problems for the practical application of research. Following a certain divergence of interests within the research community in the early 1990s, the consortium was dissolved. Subsequently, individual researchers have pursued individual paths with varying success. This research has been partly coordinated within the National Grain Program and the Innovation in Foods program. (interviews 2000.)

Apart from Melia, there are presently two other firms applying beta-glucan enriched oats in their foodstuffs products. Avena Oy is primarily a grain retailer that nonetheless has recently acquired a large share of the know-how and the related patents. Through this, Avena is becoming engaged in productive activity and the further development of oats-based products. The other firm, Bioferme Oy, has proceeded further and introduced in 1995 its first oats-based product named Yosa, which combines the functional properties of beta-glucan enriched oats bran with probiotic bacteria. The result is an oat probiotic snack that is especially suitable for a customer segment with special dietary requirements, such as diabetics, vegetarians or people suffering from certain types of celiac diseases.

Technology transfer from research to a traditional business

The case of Bioferme is an interesting example of the transfer of research to industrial application in the context of a traditional business area. Bioferme was established in 1994 as the successor of a family business named Piispanristin Mehuasema. This predecessor firm was specialized in the production of aromatic juices and tinned food made from organically grown berries and vegetables. During the 1980s and 1990s Piispanristin Mehuasema operated on a very small scale, with an annual turnover of around FIM 1 million.

The basis for the expansion from relatively traditional business towards functional foodstuffs production resided partly in the business philosophy of Piispanristin Mehuasema. The whole concept of using organically grown raw materials for foodstuffs was new at the time and Yosa essentially embodies this same concept, albeit in the context of foodstuffs with higher value added. The basic idea behind

Yosa is a patented process technology that involves the hydrothermal treatment of oat bran, followed by fermentation with selected lactic acid bacteria and bifidobacteria. Thus, Yosa draws both on research within the diary industry on the use of microbacteria in fermentation processes and the enrichment of beta glucan in the oat bran. This new combination gave Yosa favorable nutritional and dietary properties and also constituted a major step forward for the family business. (interviews 2000.)

The history of Yosa emerges out of the joint efforts by the research community to find industrial applications for beta-glucan enriched oat bran. The patented solution related to research undertaken at the University of Helsinki, Department of Crop Production. Following extensive efforts to market the idea to the larger foodstuffs firms during the early 1990s, this small family business decided to license the full concessionary rights to the idea in 1994. In terms of competencies, the licensing decision also implied a risk, since the scaling up of the process from laboratory conditions to an industrial scale was a major effort. Moreover, the viable commercialization of the process required detailed knowledge of the responsiveness of different oats bran qualities to the process as well as the selection of the correct strain of probiotic bacteria. (interviews 2000.)

The development of Yosa was a collective and interdisciplinary project, involving researchers from the University of Turku, the patent holders at the University of Helsinki, as well as a research team focusing on the metabolic and clinical aspects of the new substance. Bioferme entered this collaborative arrangement through Tekes funding. Apart from developing the basic process further, and adjusting it for the production of a yoghurt-like flavored snack, the industrial scaling also required new investments in machinery by Bioferme. The first pilot line was constructed in close collaboration with a foreign supplier, very much on a trial-and-error basis. Meanwhile, the product idea had been specified. In 1995 Yosa was introduced to the market. Thereafter, the product was specified further and new flavors were added. An additionally important part of the commercialization related to the development of packaging techniques that would meet the specific demands of preservation and biodegradability that were part of the marketing of Yosa. During 1995–99 the turnover of Yosa gradually increased. In 1999 the first export deliveries headed for Sweden and Denmark. Presently, Bioferme has a turnover of FIM 10 million and employs some 10 people. (interviews 2000.)

5 CONCLUDING DISCUSSION AND POLICY IMPLICATIONS

Some analytical considerations

Taken together, the results emerging from both the statistical analysis and the case studies militate against straightforward causalities between levels of R&D and the sophistication or complexities of the technology and knowledge base of different industries. Despite the low complexity of innovation output and lesser R&D intensities that characterize the low-tech industries, firms evidently do rely on rather complex in-house knowledge-creating activities as well as institutional and collaborative structures. Firms in the low-tech industries are often important and advanced users of technologies and innovations originating from other industries, not least from the high-tech industries or the KIBS. Moreover, they are more or less interconnected to and often important actors in the broader sectoral system of innovation.

The irrelevance and misconceptions of measuring knowledge intensity through R&D essentially pushes issues related to innovation and the development of competencies in the low-tech industries to another level. As suggested in this report, the fact that R&D intensities and technological opportunities vary across industries distinguishes different types of industrial activity in other important ways. Thus, rather than criticizing the use or misuse of R&D statistics, it is important to highlight these other differences in order to better understand competence requirements, industrial renewal and related policy issues in these industries.

Thus far, this report has discussed the research questions spelled out in the introduction from two methodologically different but complementary viewpoints, namely through statistical analysis of the database of new products and a set of firm-level case studies. The statistical analysis was designed to capture the broader contexts of different sectors, and their distinct differences through shared features of innovation processes (technological opportunity regimes). The case studies sought to dig deeper into concrete knowledge- and competence-creating processes surrounding innovation in selected low-tech industries and representative areas of the database. In this chapter the goal is to unite these two viewpoints, and relate the discussion to the conceptual and theoretical framework developed in Chapter 2. Before proceeding, however, some analytical considerations are warranted.

Despite the advantages of combining statistical analysis and case studies, it should be acknowledged that the case studies are snapshots of innovation processes in specific firms and industries. Even though particular care was taken in the selection of the case studies, there is a trade-off between drawing, on the one hand, general conclusions about industries that are characterized by lower R&D intensities and technological opportunities in the statistical analysis and, on the other, context-specific detailed conclusions that relate more to the particular industrial fields and firms contained in the case studies. To handle this trade-off, I will try to discuss only those issues that emerge from both the statistical analysis and case studies, and thereby confirm each other. I will pay less attention to conclusions that are supportable only by the case studies and their specific contexts - the prospects and problems of the wood products and foodstuffs industries have recently been discussed at greater length elsewhere (see e.g. Salo et al. 1998; Hazley 2000).

Another analytical consideration worth ventilating is that my statistical analysis is comparative in nature, where different types of industries are compared and contrasted, while the case studies only consist of innovation processes in the low-tech industries. The danger in this is that the distinct characteristics of the discussed low-tech industries do not receive equal attention in the case studies — many of the subtler features of innovation will be indifferent to R&D intensities, while others will not. A mitigating factor in this case is the emphasis throughout this report on the coupling of contexts as they are captured through the statistical analysis and the concept of technological regimes, as well as innovation processes within firms. Thus, while similar aspects might also be important in the high-tech industries, their interrelationships with the different contexts as reflected in the statistical analysis should differ.

Competence requirements in low-tech industries

It is evident that the statistical analysis is useful for delimiting broader differences across sectors and industries. On a theoretical level, the statistical analysis also confirms that the concept of technological regime is useful, especially as applied to the present type of micro-data that abstracts from pre-defined industrial classifications and R&D intensities (compare to Pavitt 1984; Kleinknecht & Bains

1993). One important conclusion emerging from the analysis is that different types of technological opportunity regimes coexist in different types of sectors and industries irrespective of R&D intensities. This questions the empirical soundness of basing analyses on pre-defined statistical classifications that assume that the industry is a relevant unit for the analysis of innovation and industrial renewal. In fact, one important condition for the emergence of new opportunities to innovate might be the complementarities that arise through the blending and interaction of different types of regimes.

Nonetheless, there are also important and quite systematic features that separate different sectors and industries from each other by R&D intensity. In particular, innovation in the low-tech industries seems to be influenced by competitive forces and regulatory issues (competitive and regulatory regimes), while innovation in the high-tech industries depends more on science-based opportunities and the customer interface (science-based and customized regimes). One important issue in the low-tech industries is thus the appropriation of competencies and value creation in a competitive set-up characterized by maturing technologies, price competition and the ease of imitation.

Appropriation and value creation in competitive regimes

In both the wood products and foodstuffs industries, the competitive regime is reflected in continuous capital investments that increase the efficiency of production, lower price margins and erode revenues from existing products. Also, the fact that products tend to develop incrementally and are of the low-complexity type does imply that imitation is relatively easy at the product level and thus the pay-offs from innovation are lower than in the high-tech industries. Taken together, these observations capture relatively well the fact that the wood products and foodstuffs industries provide relatively limited scope for temporary monopolies through innovation, at least in the short run. Consequently, they also explain why firms tend to be less R&D intensive, as the discussion on technological regimes suggests (Klevorick et al. 1995).

One key consideration for the firms is the ability to maintain their technological lead through continuous innovation and other types of complementary activities that fends off competition. Patenting, which is often crucial in the high-tech industries, is clearly of much less strategic importance in these industries. Patenting might even have adverse effects through the isolation of competition in specific market segments that otherwise might be open to competitive procurement by public agencies. Instead, firms have to resort to other means of safeguarding and appropriating their competencies for value creation. Adhering to the qualitative case material at hand, it is relevant to ask how firms create value and maintain their competitiveness in this type of regime – indeed, the firms included as case studies are all relatively successful despite their positioning in the lowest ranking according to the OECD taxonomy of R&D intensities.

The lesser R&D intensities of the case study firms conceal a range of other complementary non-R&D activities that constitute the main source of value creation. Indeed, as the statistical analysis suggests, these firms rely on diversified knowledge bases ranging from the fine-tuning of certain core technologies and process technology, their reconfigurations and new combinations, to the development of complementary assets and extensive networks, marketing, branding and design. The competitiveness of wooden building components as a business area, for example, is upheld through continuous further development and refinement of joining and gluing techniques, product aesthetics and design. Furthermore, the competencies to develop and nurture complementary assets through partnerships with customers or retailers, subcontractors, public procurers and even competing firms are crucial.

One feature of this type of networking is a division of labor in terms of tasks along the value-added chains. Therefore the organization and management of networks related to production become relatively more important than the organization and management of research networks. This type of networking often involves the extensive use of advanced ICT-based logistics and accounting systems. In the case of the use of oats in foodstuffs, continuous incremental product and process innovation is tightly intertwined with developments on the market and with the nurturing of a strong brand name and targeted marketing. A more or less outspoken strategy is to introduce different varieties of similar products with new characteristics to uphold the brand name, while at the same time catering to new consumer segments.

More generally, the development of both complementary and co-specialized assets in production, marketing and retailing is a means by which the firms can develop mutual dependence despite their need to cater to price competition in downstream markets and other product groups (compare to Teece 1986). Complementary assets of this type are difficult to imitate since they relate to the businesses in a more fundamental and path-dependent way. The fact that new products tend to develop incrementally, and are of the low-complexity type does not imply that the business practices of these firms are necessarily east to imitate. Weak appropriability conditions at the product level might thus be coupled with stronger appropriability conditions affecting the whole industry or sector in a more fundamental sense.

In terms of March's distinction between exploitation and exploration (March 1999), the emphasis is clearly on the exploitation of existing technologies and competencies through incremental innovation along existing process and product trajectories, as suggested also in the theoretical and conceptual synthesis in Chapter 2. On the other hand, the case studies also highlight the importance of architectural innovation in more explorative high-opportunities niches (compare to Henderson & Clark 1990). This is best exemplified by the development of wooden building components and systems, where major opportunities are related to new techniques to combine different types of raw materials, such as steel, polymers and wood. These techniques enable the construction of completely new products for greater reliability and cost savings.

One typical feature of innovation in many low-tech industries is the dominance of a few large firms with strong market power, as a consequence of the need for continuous capital investments and the importance of economies of scale in production. This type of oligopolistic competition creates entry barriers, and thus slows down industrial renewal. The dominance of large firms in these industries is also evident in the light of the the case studies, especially in the grain-processing industry. Nonetheless, the case studies also suggest that there are other types of barriers that deter entrants and sustain the firms' competitive positions in particular product niches (compare to the discussion on resource position barriers in Wernerfelt 1984).

While the firms' positions primarily relate to mergers and acquisitions in the face of increasing competition, the role of accumulated production experience, high fixed investments and related technological leads, as well as customer loyalty and strong brands have also acted as barriers to entry in a more fundamental way. One clear advantage simply relates to the fact that these firms have been in their lines of business for a long time and therefore have accumulated highly sophisticated competencies to operate, adjust and maintain the production machinery and process technology. This type of accumulated excellence in production is also related to high switching costs. The development of new competencies requires new machinery and production lines for their execution, implying that diversification is expensive and risky. Moreover, entrants have difficulties in achieving this type of position in a short time.

The case of the foodstuffs industry, and the use of oats in foodstuffs, illustrates nicely the role that strong brands and consumer loyalty play as barriers to entry in these types of markets. The nurturing of the brand name is a strategic priority, through the introduction of incremental innovations to established products. The case of Yosa is somewhat different, where entry occurred through a unique patented technological innovation in a narrow market niche that evidently was deemed unprofitable or excessively risky by the larger incumbents.

Incremental innovation and the close link between the development of process technology and new products that stands out in the statistical analysis is confirmed and concretized further in the case studies. In all four firms, new products have emerged out of the investment in new machinery or the fine-tuning of existing production methods. Moreover, the above-mention production experience that the firms possess is based on highly experience-based accumulated knowledge that typically seems to be tied up to specific individuals within the firms. This type of knowledge has been described by, among others, Laestadius (1998) as inductive rather than deductive, practical rather than theoretical, or tacit and implicit rather than codified and explicit (compare also to Polyani 1967).

The further upgrading and various generations of new products examined in greater detail in the case studies are associated with the solution of a range of relatively complex but practical engineering problems related to parameter variations of the machinery or the combination of available technologies, components and concepts in new and creative ways. The firms have also acted as lead users in collaboration with equipment suppliers (von Hippel 1988). Alternatively, in the foodstuffs industry, the major technological challenge relates to the fine-tuning of machinery to achieve the optimal blends and catalytic properties of the raw material components. More generally, this suggest that the flow of both embodied and disembodied technology to the low-tech industries is not a passive process from the perspective of the users, as is often portrayed in macro-economic studies. Rather, these competencies to apply inward technology flows seem to be close to the core competencies of the firms, and are very difficult to imitate.

One interesting issue in the case studies is the importance that the firms assign to cost-efficient mass-customization, or small variations in products retailed to specific customer segments. On the other hand, the statistical analysis seems to suggest the opposite, namely that customized regimes are more characteristic of the high-tech industries. The interpretation of this somewhat conflicting result can be explained in two ways. Given that customers are regarded as being important irrespective of sector and industry, it might be the case that customization is still relatively more important in the high-tech industries than in the low-tech industries. This makes intuitive sense, since products tend to be more complex, requiring more specifications and closer collaboration with customers. Alternatively, the definition of the customized regime in the principal component analysis is imprecise and captures some other feature of collaboration with customers that matters more in the high-tech industries. The role of mass-customization in the low-tech industries is clearly an important aspect that would need greater attention in further research.

Absorbing technological opportunities

It seems evident from the statistical analysis that, compared to the low-tech industries, the high-tech and high-opportunity industries are characterized by a greater reliance on the sciences and new technologies, closer ties to the universities and research organizations (science-based regime) and generic knowledge bases (generic regime). Nonetheless, this does not imply that technological opportunities are non-existent in the low-tech industries. In fact the case studies to a lesser or greater degree illustrate how the firms have managed to react to technological opportunities in specific product niches. In other words, there are 'pockets' of high technological opportunities despite low R&D intensities for these industries as a whole. One important question in this context concerns the mechanisms that determine why only some firms 'break the pattern', apply new technologies or become engaged in science-based innovation. Another important and related question concerns the development of absorptive capabilities by means other than in-house R&D.

As suggested above, a commonality running through the case studies is the fact that the competitive regime engulfing these industries leads firms along cost-cutting trajectories characterized by continuous capital investments and efficiency considerations. Typically, the production of incrementally evolving low-complexity products through efficient production methods is still the main source of revenue. Therefore there might be few incentives to set aside resources also for the development of completely new products and business areas with higher value-added. In this sense, developing what Teece et al. (1997) call dynamic capabilities to simultaneously exploit existing product lines and explore completely new ones is no easy task. This is because a major break in the established trajectory implies high switching costs and risky investments due to the capital intensity of production – it is easier (and more profitable in the shorter run) to stick to existing routines. While this type of path-dependency slows down industrial renewal, it is nonetheless not self-evident that the emphasis should always be on exploration as a goal in itself. Rather, the key strategic issue seems to be to strike a balance between exploiting existing competencies, products and businesses and developing entirely new ones. Since the potentials for temporary monopolies are limited, failure in exploration has to be balanced by success in exploitation.

One interesting observation that emerges especially from the case studies is the conflicting interests and tensions that seem to be involved in collaboration spanning industrial and cognitive borders, as a reflection of deeper issues hampering exploration and industrial renewal. In particular, the typical pattern of innovation characterized by incremental change and the combination of different vintages of technologies leads to the confrontation of paradigms, heuristics or thought worlds (compare to Dosi 1982; Douglas 1986 or Brown & Duguid 1991). One observation that Laestadius (2000) makes is that technology diffusion is hampered by the confrontation of the genuine science-based community surrounding the application of biotechnology and the traditional engineering profession in the pulp & paper industry. Similar types of mechanisms and problems are evident both in the case of wooden building components and the use of oats in foodstuffs.

In the wood products industry, both case study firms have faced resistance from traditional construction heuristics using traditional materials, such as cement and steel. These types of resistance are not only related to economic considerations, but also depend on the cognitive frame and mind-set of the involved actors and institutions. One key question concerns the more widespread acceptance of wood as a building material. In the cases considered the role of public initiatives for fostering the use wood has been important at least in the Finnish context. In the case of the foodstuffs industry the confrontations mainly concern the blending of the scientific and traditional engineering heuristics within the firms. On the other hand, the fact that consumers tend to be sensitive towards new types of foodstuffs is clearly also apt to discourage firms to introduce radically new products and concepts – genetically modified foodstuffs are good examples

The clearest example of the appropriation of technological opportunities is Yosa. In this case, research related to nutrition and health was harnessed commercially through close ties to the scientific community. It is an interesting example of a spin-off from a university in an industry slow to change, which seems to suggest that a new organizational setting is needed to overcome some of the conflicting interests and tensions involved in the blending of the scientific and traditional engineering communities. Nonetheless, all the other case study firms have also participated in science-based interdisciplinary networks to a greater or lesser extent.

Given that the ability to integrate new technologies into existing businesses is quite central for all of the case study firms, and for the low-tech industries in general, the accumulation of capabilities to absorb this external knowledge is a crucial ingredient in their long-term competitiveness. Here the concept of absorptive capabilities is both interesting and confusing (Cohen & Levinthal 1990). The confusing part relates to the fact that the firms devote modest levels of expenditures to R&D and do not rely on scientists, yet they are more or less successful examples of firms that break the pattern and introduce new products to the markets.

With reference to the conceptual and theoretical discussion in Chapter 2, the type of absorptive capabilities that seems to be characteristic to the case study firms is indeed better captured through the concept of transformative capabilities, where firms draw on new configurations of existing storehouse technologies residing within firms rather than the development of new ones through goal-oriented R&D and external collaboration (Garud & Nayyar 1994;compare also to Henderson & Clark 1990). Apart from perhaps Yosa, all of the case studies point to the importance of the firm's ability to transfer and continuously reactivate their storehouse technologies over time in response to changes in the market or internally generated opportunities. Moreover, in all cases the innovation processes and the development times of new products are longish and difficult to anchor in time since they are more or less continuous.

On the other hand, all the included case study firms have also been involved in collaboration with external experts or research groups in universities and research organizations. The resulting division of labor between the firms and the research groups is typically one where the latter provide the explorative avenues, while the firms couple this with the exploitation of available techniques and product palettes. In the case of the foodstuffs industry the necessity for clinical research is also apt to increase the requirement of R&D-related capabilities, thereby offering advantages for larger firms with corporate R&D labs.

One especially pertinent feature of the external collaboration is the role played by gatekeepers, or certain key individuals acting as intermediaries between research and industrial application (compare to Allen's 1977 concept of technological gatekeepers). These individuals typically have a long employment history with the firms as well as close personal ties to the relevant scientific community. As Tushman & Katz (1980) also emphasize, these gatekeepers are able to reduce the cognitive distance and mitigate the confrontation of paradigms, thought worlds or communities of practice at the intersections of the scientific community and the more practical engineering heuristics that prevail in the day-to-day business of the firms. The downside is that the reliance on a couple of gatekeepers, and the lack of more widespread in-house R&D capabilities, might also present problems in the face of a radical shift in technology that potentially might constitute a serious threat to the very existence of the firms.

Regulatory inertia, competing practices and market concepts

A final issue that emerges from both the statistical analysis and the case studies relates to the role of regulations, legislation and standards (the regulatory regime). It might well be the case that the dynamism of new high-tech industries depends largely on greater efforts towards regulatory reform and standardization, while the lesser dynamics of the older low-tech industries is partly explainable by regulatory inertia and the lack of standardization in many fields. As one informant in the wood products industry expressed it somewhat starkly: "...look at the telecom industry, they are presently developing the third generation mobile standard…we do not even have the first one for starters."

In fact, products from many low-tech industries are typically embedded in larger infrastructures (construction is a good example) and thus regulatory changes and standardization might have especially profound effects. The achievement of a pan-European standard for using wood in construction would be a case in point. The uncertainties and rigidities related to the use of health claims in the foodstuffs industry is another example. Taken together, these types of problems and potentials probably explain why the regulatory regime turns out to have a high loading in the principal component analysis of the low-tech industries.

Regulatory inertia and the lack of standardization is partly a reflection of the above-discussed conflicting interests and tensions that seems to be involved in collaboration spanning industrial and cognitive borders. On an institutional level, the cognitive frames and mind-sets are cemented in the form of regulations, laws and norms. For example, the widespread introduction of wood as a viable option to traditional materials used in construction is hampered by existing safety norms as well as different regulations on different markets. In the specific case of the further expansion of wooden bridges as a business area, the expansion was made possible through coordinated involvement of public sector regulators and procurers. More generally, the recent public initiatives fostering wooden building are a good illustration of the possibilities in this field (for example, the Sibelius Concert Hall in the city of Lahti). For LVL, marketing and exports required extensive joint ventures, trials and testing for each foreign market separately.

In the case of the use of oats in foodstuffs, sales benefited greatly from clinical research results in the US that paved the way for using health claims in marketing. In other cases, regulatory inertia and a lack of standards have been too obstructive, leading to discontinuation. A related problem is that raw-material-based products are typically heterogeneous by nature and require a long period to sort out the impact of product performance, e.g. in terms of the weather resistance of wooden bridges or the effects on human health of new foodstuffs. These characteristics of the products make standardization more difficult.

In addition to institutionalized cognitive frames and mind-sets, there are strong vested interests involved due to competition. New products harnessing new materials and concepts face resistance from traditional materials and from established customer and supplier relationships. Thus, the use of wood in construction faces strong opposition from users of steel and cement, while oats-based products claim the same customers as other well-established substitutes with similar nutritional properties. This competition easily results in falling prices, which are more difficult to bear for the entrants with a lesser foothold on the market. Moreover, rapid imitation might easily erode temporary monopoly profits with feedbacks for further expansion.

Policy implications

A starting point for a policy discussion is that the low-tech industries are not necessarily doomed to stagnating demand and lack of technological opportunities, despite the fact that the maturity of the present technologies and markets imply lower pay-offs from R&D. It is quite clear that the issue is not the design of end-game policies that would cater to the gradual decline and exit of firms in the low-tech industries. Quite the contrary, despite the fact that the future of certain low-tech sectors might be bleak in the long run, there are also significant niches of technological opportunities and firm growth that should be nurtured further.

The policy issues that deserve most attention concern the design of specific policy initiatives that complement firms' own resources during innovation in a way that would also take into consideration both the specificities of innovation in low-tech industries and their broader framework conditions. There is clearly also a need to include an international dimension in the discussion even though many firms in the low-tech industries tend to be oriented to their domestic suppliers and markets.

Striking a balance between supporting unilateral and collaborative R&D

It would be wrong to suggest that policymakers should redirect R&D subsidies from the high-tech industries to the low-tech industries. It would also be wrong to suggest that the ultimate goal of policy should be to raise both public and private outlays on R&D in the low-tech industries to similar levels as those prevailing in such industries as electronics, machinery or telecom. Indeed, an interesting result of both the statistical analysis and the case studies is that public support for R&D is not negligible in the low-tech industries, even though a certain polarization is evident. This is best illustrated in Table 14, which presents survey results on the share of new products with public R&D support by R&D intensity.

Sector	N	% Share of new products with public R&D support
All manufacturing	548	64
High R&D	45	89
High-medium R&D	304	64
Low-medium R&D	89	73
Low R&D	110	44

Table 14. The share of new products with public R&D support by R&D intensity.

According to the table 64 percent of all the new products covered by the survey have received public support for their development. Across sectors the new products originating from the low-tech industries have received less support than the average, while new products originating from the high-tech industries have received significantly more than the average. Nonetheless, when looking beyond the aggregate sectors in Table 14a in the Appendix, the low shares in low-tech are largely due to new products originating from the foodstuffs industry. Overall, the distribution of public R&D funding also seems to reflect quite well the distribution of private sector R&D. In line with what was said above, the conclusion could therefore be that, relatively speaking, the low-tech industries are not in a disadvantaged position. This interpretation is also in line with what was learnt from the case studies, namely that public R&D sources are made available and that these matter.

An especially important issue seems to be related to the diffusion of new emerging technologies to the low-tech industries as a means of transforming and renewing existing areas of strength in these industries. This would suggest that the focus of policy should be on network-facilitating policies that connect industrial communities from the high-tech and low-tech industries around generic pre-paradigmatic technologies, such as ICT, new materials or biotech.

In the Finnish context a focus on network-facilitating policies is compatible with the tradition of research and technology programs commissioned primarily by the Ministry of Trade and Industry, Tekes, and more recently the Academy of Finland. Table 15 presents survey results on the role that research and technology programs have played in collaboration during the development of the new products by R&D intensities, i.e. the table gives some indication of whether these type of programs have a greater impact in the low-tech industries.

Sector	N	% Share of new products with public programs regarded as important
All manufacturing	536	21
High R&D	44	25
High-medium R&D	299	20
Low-medium R&D	88	25
Low R&D	105	17

Table 15. The share of new products with public programs regarded as important during collaboration by R&D intensity.

Interestingly, the table suggests that R&D intensity does not seem to differentiate significantly between new products in this respect. Referring to the above, public programs nonetheless seem to be regarded as relatively more important in the low-tech industries compared to unilateral R&D subsidies directed to individual firms and products when tables 14 and 15 are compared (again the foodstuffs industry stands out as an exception when looking beyond the aggregate sectors in Table 15a in the Appendix). If this is so, then the case studies also give some good illustrations of the potential problems that the policymaker might face during the set-up of such collaborative projects. Reference can be made to the confrontation of paradigms, heuristics or thought worlds that is evident in the case of the integration of science-based communities and explorative research with the more experience-based engineering heuristics and exploitation that prevail in both wood products and foodstuffs industries. In this sense there might exist some quite serious mental or cognitive rigidities that need to be acknowledged and catered to.

Another potential problem in this context concerns the incentives for firms on cost-cutting trajectories to set aside resources for longer-term development of competencies and new technology at the costs of short-term profits. The integration of emerging technologies into traditional activities requires risk-taking beyond what might be deemed viable. A particular challenge relates to timing. It is especially during the early pre-paradigmatic stages of the emergence of new technologies that their potentials should be made evident. At this stage the risks involved could be mitigated through public action (it is beyond the scope of this project to assess the role that venture capital plays in these industries, though). On the other hand, the breaking of cost-cutting trajectories should not necessarily be a goal in itself. As suggested above, the trade-off between exploitation and exploration is a delicate one in these types of low-opportunity industries.

General framework conditions

Apart from the importance that both public R&D subsidies and research and technology programs can play in the low-tech context, it seem clear that these types of industries might be particularly sensitive to general framework conditions that are sometimes outside the sphere of influence of innovation or technology policy. This is so because the case studies, and to a certain extent also the statistical analysis, point towards the importance of a range of other activities complementary to R&D that might be relatively more important in these industries. Thus, there is a particularly strong case here for the coordination of different types of policies in the overall policy framework.

The firms included as case studies expressed a general concern that they suffer from a shortage of workers with practical and traditional engineering skills due to the lesser public image of these industries. Therefore educational policies have a role to play in catering to the peculiar demand that many firms seemingly have e.g. in the wood products industry. The role of regional initiatives, polytechnics and vocational schools is probably especially important since many smaller firms and sawmills are deeply rooted in their local milieu, not least due to their reliance on locally sourced raw materials and their dependence on minimizing transportation costs. This is especially true for the wood products industry, but also for the foodstuffs industry to a certain extent.

Another example of the need for coordination relates to the interrelationships between market structures and innovation. While it is clear that market structures have an affect on innovation, the exact nature of this interrelationship is unsettled, also in the light of the empirical results discussed in this paper (for an overview, see Cohen 1995). However, as a casual observation it is worth highlighting that anti-trust legislation might have especially significant effects also on innovation, given that large size often follows from the need for continuous capital investments, which in turn relates to incremental product innovation through the development of process technology. In the case of the foodstuffs industry, for example, the mergers and acquisitions that have been necessary for the overall competitive situation might not have been favorable from the perspective of industrial renewal through exploration and entry – indeed it seems that smaller firms are the more explorative ones at present even though their prospects to get a foothold on the markets might be bleaker.

Standardization and legislation is another area where much could be done to foster the innovation potential of the industries studied here. Clearly, the wood products industry would benefit greatly from the further development of national construction standards, as well as the creation of a pan-European wooden construction standard. Likewise, the development of new products in the foodstuffs industry is very sensitive to the stipulation of health-claim legislation governing marketing, especially in the case of functional foodstuffs as a new field with much potential. The uncertainties associated with legislation governing genetically modified raw materials in foodstuffs are another case in point. While standardization and legislative change is a possible and viable policy measure in the national context, international efforts are more problematic from the small country perspective. Moreover, consumer legislation or other types of information and promotion campaigns related to marketing and branding are also important.

Finally, the sustainability of the research infrastructure warrants some discussion. It appears to be the case that the conflicting interests and lack of long-term commitment to R&D amongst many firms are reflected in the erosion of the resources and scope of research activities undertaken at universities and in research organizations. While a certain degree of crowding-out of the traditional sciences might be warranted due to the evident growth in importance of others, it would seem to be of great importance to secure a necessary level of basic research. This is essential since firms in the low-tech industries for quite pragmatic and understandable reasons are more clearly oriented towards exploitative activities compared to the high-tech industries. They nonetheless rely, in some cases significantly, on the more explorative type of research that is undertaken at the universities. Thus the erosion of the research infrastructure would also seriously undermine the absorptive capability of the firms. Moreover, securing the supply of qualified employees from the universities also requires a competitive research infrastructure.

Suomenkielinen tiivistelmä

INNOVAATIOT JA OSAAMINEN – erityistarkasteluna perinteisten alojen innovaatiotoiminta

Johdanto

Viime aikoina on korostettu tiedon ja oppimisen keskeistä merkitystä teollisuusmaiden kilpailukyvylle, taloudelliselle kasvulle ja hyvinvoinnille. Muun muassa OECD:n piirissä ja myös Suomessa osaamis- ja oppimisyhteiskunta ovat usein käytettyjä käsitteitä, joiden avulla suunnitellaan ja perustellaan innovaatiopoliittisia toimenpiteitä. (Lundvall & Borrás 1997; Valtion tiede- ja teknologianeuvosto 2000.) Käsitteet liitetään voimakkaasti osaamisen ja oppimisen kannalta lupaavimpina pidettyjen korkean teknologian aloille. Vaikka onkin ilmeistä, että informaatioteknologian merkitys on ollut keskeinen Suomen teollisuuden viimeaikaisessa uudistumisessa, innovaatiopolitiikan liiallisessa fokusoimisessa piilee myös vaaroja. Voidaan todeta, että niin Suomessa kuin muissakin teollisuusmaissa on paljon perinteisiä osaamisalueita, jotka tarjoavat jatkossakin runsaasti kehittämismahdollisuuksia.

Korkean teknologian näkyvä rooli on osoitus myös siitä, että meillä ei ole käytettävissä innovaatioindikaattoreita, joilla kyettäisiin tuomaan esiin innovaatiotoiminnan toimialakohtaisia eroja ja innovaatiotoiminnan monimuotoisuutta yleisemmin. Yleisesti käytettyjen OECD:n korkean teknologian tilastojen avulla kuvataan eri maiden teknologian tasoa eri toimialojen t&k-panostusten avulla. Näin määritellään korkean teknologian aloiksi lähinnä elektroniikka, teleala ja lääkeala, joiden t&k-panostuksen osuus liikevaihdosta ylittää 4 prosenttia. Matalan teknologian alojen t&k-panostuksen osuus liikevaihdosta on alle 1 prosenttia, ja keskitason teknologian alojen vastaava osuus on 1–4 prosenttia. Tältä pohjalta korkean teknologian alojen osuus tuotannosta ja viennistä on Suomessa kasvanut voimakkaasti viime vuosina, paljolti matalan teknologian alojen kustannuksella. Toisaalta tilastojen taustalla on ennen muuta Nokia, jonka kasvu on johtunut pikemminkin yrityskohtaisista kuin toimialakohtaisista tai innovaatiopoliittisista tekijöistä. Tarkastelun ulkopuolelle jää myös huipputeknologian ja osaamisen leviämisen myötä tapahtuva eri alojen vuorovaikutus, ja näin myös perinteisten toimialojen uudistumismekanismit. Vieläkin ongelmallisempi on se tosiasia, että t&k-intensiivisyys on vain yksi mahdollinen innovaatiotoiminnan ja sen keskittymisen indikaattori. Muun muassa Laestadius (1998) korostaa, esimerkkinä pohjoismainen paperiteollisuus, että OECD:n käyttämä t&k-intensiivisyyteen perustuva indikaattori yliarvioi tiedepohjaisten toimintojen merkityksen tuotannolliseen ja kokemuspohjaiseen tietoon verrattuna. Innovaatiokirjallisuudessa puhutaan entistä enemmän arkipäiväisestä tai kokemuspohjaisesta "hiljaisesta tiedosta" yritysten innovaatiotoiminnan ja kilpailukyvyn avaintekijänä.

Huolimatta korkean teknologian tärkeydestä ja sen viimeaikaisesta kasvusta on selvää, että matalan teknologian, tai perinteisten alojen, uudistumismekanismien ja tarpeiden ymmärtäminen on ja pysyy ajankohtaisena. Innovaatiopolitiikan kannalta on välttämätöntä identifioida kasvumahdollisuuksia myös korkean teknologian ulkopuolelta, tai sen muille aloille tarjoamista soveltamismahdollisuuksista. Samoin on tärkeätä siirtää tarkastelukulma olemassa olevien tilastojen ja yksipuolisten indikaattoreiden taakse, konkreettisen innovaatiotoiminnan tasolle. Vain tätä kautta kykenemme kunnolla ymmärtämään perinteisten alojen osaamisvaatimukset, muutosprosessit ja kehittämistarpeet. Nämä kysymykset ovat olleet tämän tutkimuksen lähtökohtana.

Tutkimuksen teoreettiset ja käsitteelliset lähtökohdat

OECD:n korkean teknologian tilastojen kritiikki voi yhtäältä kohdistua käytettyyn käsitteistöön, ja varsinkin tiedon, osaamisen ja teknologian määrittelemiseen. Toisaalta voi olettaa, että t&k-intensiivisyys on käypä indikaattori tietyntyyppisen innovaatiotoiminnan kuvaamiseen. Innovaatiotutkimuksessa oletetaan t&k-tilastojen kuvaavan varsin hyvin eri alojen teknologisten mahdollisuuksien tasoeroja (Klevorick et al. 1995). On esimerkiksi melko selvää, että tieteellis-tekniset mahdollisuudet ovat telealalla tai lääketeollisuudessa tällä hetkellä suuremmat kuin puutuote- tai metalliteollisuudessa, missä tärkeimmät peruskeksinnöt on jo tehty. Toisaalta teknologisten mahdollisuuksien tasoerojen lisäksi myös eri alojen laajemmat kontekstit vaikuttavat innovaatiotoiminnan dynamiikkaan ja luonteeseen. Tähän liittyen käsite "teknologinen regiimi" soveltuu hyvin toimialakohtaisten erojen tarkasteluun.

Malerba ja Orsenigo (1997) tarkoittavat teknologisella regiimillä niitä tekijöitä, jotka vaikuttavat innovaatiotoiminnan dynamiikkaan ja osaamistarpeiden kehittymiseen. Näitä ovat teknologisten mahdollisuuksien taso ja sisältö (esimerkiksi tieteen tai käyttäjien ja asiakkaiden merkitys innovaatiotoiminnan lähteinä), innovaatiotoiminnan suojaamiskeinot (esimerkiksi hallintaoikeus, näennäisinnovaatiot, tuotteen kompleksisuus tai yritysten kyky suojata toimintatapoja laajemmassa mielessä), sekä markkinoiden dynamiikka ja vallitsevat kysyntäolosuhteet. Olennaista tässä on eri muutosvoimien yhteisvaikutus, josta voidaan johtaa erilaiset innovaatiotoiminnan ja osaamisen erityispiirteet. Teknologisen regiimin avulla halutaan myös korostaa innovaatiotoiminnan juurtumista ja teknologisen muutoksen etenemistä taloudellis-teknisten kompromissien kautta tiettyyn suuntaan (Nelson & Winter 1982; Dosi 1988).

Tutkimuksen empiirisessä osassa tarkastelun pohjana on ollut uusi laaja kyselypohjainen innovaatiotietokanta. Sen avulla on mahdollista tutkia toimialakohtaisia eroja innovaatiotoiminnassa, myös käsitteen teknologinen regiimi kautta. Tilastollista tarkastelua täydennetään valikoiduilla yritystason tapaustutkimuksilla. Tilastollisen aineiston ja tapaustutkimusten yhdistäminen edellyttää, että johtopäätökset kyetään ankkuroimaan teoreettiseen kehikkoon, jonka avulla voidaan eritellä erilaisten toimialojen ja osaamisvaatimusten vuorovaikutussuhteita. Yksi käyttökelpoinen lähtökohta on ns. resurssipohjainen yritysteoria (ks. Foss 1997).

Resurssipohjaisessa yritysteoriassa korostetaan erityisesti yritysten kompetenssien ja erityispiirteiden yhteensovittamista osana yritysten kilpailukykyä ja kasvua. Yritysten kompetenssit määräytyvät paljolti inhimillisistä ja fyysisistä resursseista. Niiden käytön tehokkuus riippuu yritysten tavasta organisoida toimintoja ja hyödyntää osaamista ja tietoa kaupallisesti. Tästä näkökulmasta keskeistä yritysten menestymisessä ei ole se, onko taustalla korkeaa teknologiaa, tieteellisiä läpimurtoja tai merkittäviä innovaatioita. Yritykset voivat menestyä, ja menestyvätkin, arkipäiväisillä tuotantoa koskevilla ongelmanratkaisutaidoillaan, organisoimalla taitavasti alihankintaverkostoja, kehittämällä täydentäviä varantoja yhteistyönä asiakkaiden ja muiden yritysten kanssa sekä tekemällä jatkuvasti pieniä parannusinnovaatioita tai yhdistelemällä uudella tavalla olemassa olevia innovaatioita. Resurssipohjaisen yritysteorian avulla voidaan tarkastella t&k-toiminnan merkitystä muuntyyppiseen osaamiseen ja oppimiseen verrattuna. Toinen tärkeä näkökulma, kilpailutekijöiden kehittämisen ohella, on kilpailutekijöiden jäljittelyn ehkäiseminen. Taloustieteilijät korostavat patentoimisen kautta saavutettavan hallintaoikeuden merkitystä. Resurssipohjainen yritysteoria painottaa myös rutiinien ja hiljaisen tiedon, tai sosiaalisen pääoman roolia yritysten kilpailukyvyn tärkeänä osana (Nelson & Winter 1982; Nahapiet & Ghosal 1998).

Keskeiset tulokset

Tutkimuksessa käytetty innovaatiotietokanta sisältää tietoja noin 1 600:sta vuosina 1985–98 kehitetystä suomalaisesta innovaatiosta.[1] Innovaation määrittelemisen lähtökohtana on ollut markkinoille tuotu keksintö, joka on ollut yrityksen

[1] Tietokanta liittyy myös Tekesin rahoittamaan 'Suomalainen innovaatio (Sfinno)' -tutkimusprojektiin.

kannalta täysin uusi tai pieni parannus olemassa oleviin tuotteisiin. Näin innovaatiotietokanta sisältää pääasiassa teollisuuden uudistumisen kannalta tärkeimpiä tuoteinnovaatioita yritysten omaan käyttöön kehitettyjen prosessi-innovaatioiden sijasta. Tietokannan innovaatiot identifioitiin haastattelemalla eri alojen asiantuntijoita sekä käymällä systemaattisesti läpi eri alojen ammattilehtiä ja suuryritysten toimintakertomuksia. Kyselyn avulla kerättiin lisätietoja noin 800 innovaatiosta, joista 569 edustaa valmistavaa teollisuutta. Kyselyaineisto antaa näin hyvän mahdollisuuden analysoida toimialakohtaisia eroja innovaatiotoiminnassa.

Korkean teknologian nopea kasvu 1990-luvulla näkyy hyvin myös tässä innovaatiolähtöisessä aineistossa. Merkillepantavaa on kuitenkin myös se, että perinteisten matalan teknologian alojen osuus innovaatioista on suuri ja pysyy ajassa lähes muuttumattomana. Kun yritysjoukkoa tarkastellaan lähemmin, merkillepantavaa on myös uusien suuryritysten suhteellisesti tärkeämpi rooli näillä aloilla. Lisäksi innovaatioiden kompleksisuusaste on selvästi alhaisempi matalan kuin korkean teknologian aloilla.

Yleisen käsityksen mukaan perinteisillä, kypsillä matalan teknologian aloilla innovaatiotoiminnan pääpaino on — hintakilpailun keskeisyyden takia —tuotantomenetelmien kehittämisessä prosessi-innovaatioiden avulla. Innovaatiolähtöinen tarkastelu osoittaakin, että perinteisillä matalan teknologian aloilla keskitytään ydinteknologian kaupallistamisen ja järjestelmäosaamisen kehittämisen sijasta tuotantomenetelmien kehittämiseen. Tuotantomenetelmien ja uusien tuotteiden kehittämisen välillä on kuitenkin hyvin läheinen yhteys, joka kyseenalaistaa tiukan eron tekemisen tuote- ja prosessi-innovaatioiden välillä varsinkin näillä aloilla. Toisaalta perinteisillä matalan teknologian aloilla hyödynnetään ja yhdistellään myös monenlaista taustaosaamista. Tärkeä tulos on lisäksi se, että innovaatioiden uutuusasteet yritysten kannalta ovat korkean ja matalan teknologian aloilla samankaltaiset huolimatta teknologisten mahdollisuuksien tasoeroista. Markkinoiden kannalta perinteisten matalan teknologian alojen innovaatiot ovat kuitenkin keskimääräistä useammin pieniä parannuksia olemassa oleviin innovaatioihin.

T&k-panostusten suhteellisen alhaisten tuottojen takia teknologisten mahdollisuuksien identifioiminen ja kaupallinen hyödyntäminen varsinkin tuoteinnovaatioiden kautta on erityishaaste näillä aloilla. Toimialakohtaisten erojen ymmärtäminen innovaatioiden lähteissä on myös keskeistä innovaatiopolitiikan vaikutusmahdollisuuksien parantamiseksi. Kuten taulukosta 1 käy ilmi, hintakilpailu ja kilpaileva innovaatio sekä ympäristösuojelulliset tekijät ovat perinteisillä matalan teknologian aloilla keskeisessä asemassa innovaatioiden synnyssä. Vastaavasti korkean teknologian aloilla korostuu tieteellisten läpimurtojen ja uusien teknologioiden merkitys. Toisaalta, markkinaraon ja asiakkaiden merkitys on suurin piirtein yhtä suuri kaikilla aloilla. Toinen tähän liittyvä näkökulma on eri yhteistyökumppaneiden merkitys teknologisten mahdollisuuksien sisäistämisessä ja soveltamisessa innovaatiotoiminnassa. Taulukossa 2 korostuu asiakasyhteistyön merkitys sekä yliopistojen ja tutkimuslaitosten varsinkin korkean teknologian aloilla. Mielenkiintoista on kuitenkin se, että perinteisillä matalan teknologian aloilla yrityksen sisäisellä yhteistyöllä on suurempi merkitys kuin korkean teknologian aloilla.

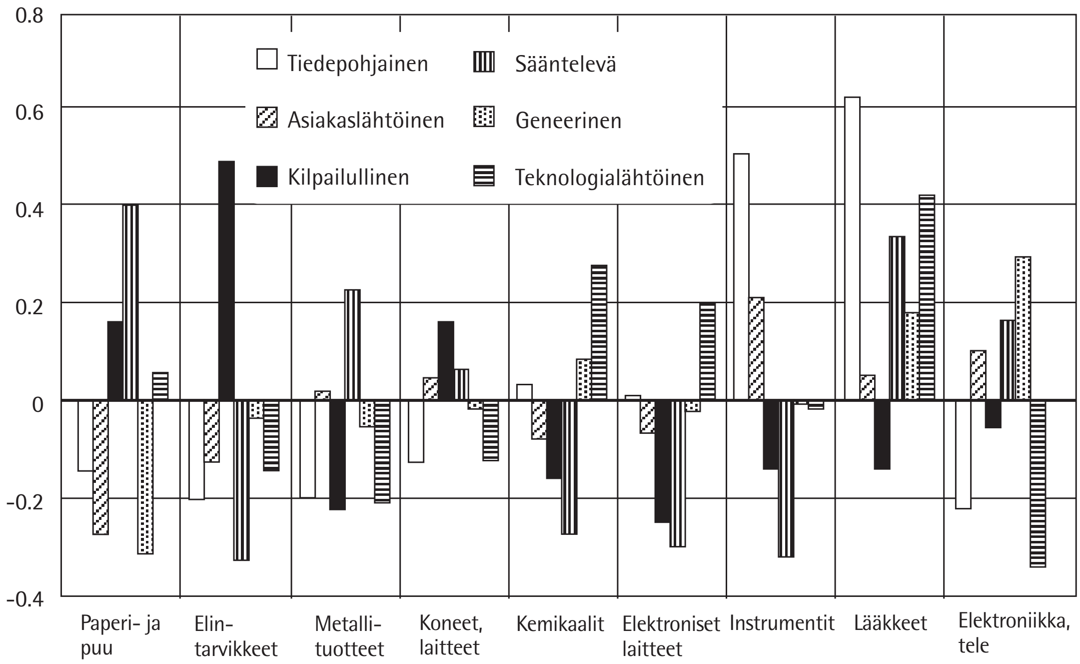
	Teollisuus yhteensä	Korkea teknologia	Korkea keskitason teknologia	Matala keskitason teknologia	Matala teknologia
Hintakilpailu	0.95	0.57	0.90	1.01	1.21
Kilpaileva innovaatio	0.86	0.77	0.86	0.76	0.95
Markkinarako	2.28	2.50	2.25	2.22	2.32
Asiakkaat	2.06	2.20	2.06	2.13	1.95
Julkiset hankinnat	0.31	0.45	0.29	0.28	0.32
Tieteellinen läpimurto	0.49	1.00	0.44	0.39	0.51
Uudet teknologiat	0.97	1.11	1.01	0.85	0.88
Teknologiaohjelma	0.54	0.50	0.52	0.63	0.51
Ympäristötekijät	0.86	0.18	0.83	1.18	0.99
Regulaatiot	0.74	0.82	0.70	0.87	0.70
Lisenssi	0.18	0.50	0.14	0.16	0.17

Taulukko 1. Innovaatioiden lähteet toimialojen t&k -intensiivisyyden mukaan (keskiarvoja). N=553

	Teollisuus yhteensä	Korkea teknologia	Korkea keskitason teknologia	Matala keskitason teknologia	Matala teknologia
Oma konserni	0.62	0.54	0.52	0.73	0.84
Asiakkaat	1.52	1.55	1.63	1.54	1.19
Konsultit	0.39	0.37	0.40	0.45	0.34
Alihankkijat	0.82	0.76	0.85	0.80	0.81
Yliopistot	0.65	1.12	0.61	0.66	0.53
VTT	0.71	0.31	0.78	0.89	0.53
Muut tutkimuslaitokset	0.42	0.82	0.37	0.35	0.44
Kilpailijat	0.26	0.32	0.27	0.19	0.26

Taulukko 2. Eri yhteistyöpartnereiden merkitys innovaatioiden kehittämisen kannalta toimialojen t&k-intensiivisyyden mukaan (keskiarvoja). N=479

Teknologisten mahdollisuuksien tasoerojen lisäksi on otettava huomioon myös innovaatiotoiminnan laajempia konteksteja. Tähän tarkoitukseen sovellettiin pääkomponenttianalyysia. Kuvassa 1 esitetään pääkomponenttianalyysin tulokset toimialojen t&k-intensiivisyyden mukaan, jolloin innovaatiotoiminnan toimialakohtaisia eroja voidaan tarkastella aineistolähtöisesti. Pääkomponenttianalyysissä erottuvat kuusi pääkomponenttia, jotka on nimetty teknologinen regiimi -käsitteistön avulla tiedepohjaiseksi, asiakaslähtöiseksi, kilpailulliseksi, säänteleväksi, geneeriseksi ja teknologialähtöiseksi regiimiksi.



Kuva 1. Pääkomponenttianalyysin tulokset toimialan t&k-intensiivisyyden mukaan.

Lyhyesti voidaan todeta, että pääkomponenttianalyysin tulokset tukevat edellä esitettyjä huomioita. Perinteisten matalan teknologian alojen innovaatiotoiminnan erityispiirteitä ovat pienet parannusinnovaatiot ja kilpailuolosuhteet (hintakilpailu ja kilpailevan innovaation luoma uhka) sekä kilpailevat yritykset innovaatioiden lähteinä (kilpailullinen regiimi). Nämä tekijät nousevat tärkeiksi etenkin elintarvike- ja metsäteollisuudessa, mutta osittain myös kone- ja laiteteollisuudessa. Korkean teknologian aloilla korostuvat tiedepohjaiset täysin uudet innovaatiot, joiden lähteinä ovat tieteelliset läpimurrot, uudet teknologiat ja yhteistyö yliopistojen ja tutkimuslaitosten kanssa (tiedepohjainen regiimi). Toisaalta sääntelevän regiimin merkitys on tärkeä perinteisillä aloilla ja asiakaslähtöisen regiimin korkean teknologian aloilla. Tämän mukaan lainsäädännölliset ja ympäristösuojelulliset tekijät suuntaavat innovaatiotoimintaa keskeisesti varsinkin sellaisilla aloilla kuin metsä- ja metallituotteet sekä koneet ja laitteet, ja osittain myös lääke- ja elektroniikkateollisuudessa. Asiakaslähtöisyys sen sijaan on keskimääräistä tärkeämpi esimerkiksi instrumenteissa sekä elektroniikka- ja lääketeollisuudessa. Geneerinen regiimi, jossa korostuu monien eri yhteistyökumppaneiden merkitys, on vallitsevampi korkeassa teknologiassa.

Tutkimuksen tavoitteena oli päästä t&k-tilastojen taakse tarkastelemaan konkreettista innovaatiotoimintaa ja tätä kautta ymmärtää paremmin perinteisten matalan teknologian alojen osaamisvaatimuksia sekä muutosprosesseja ja -tarpeita. Tilastollinen tarkastelu toi esiin tärkeitä toimialakohtaisia eroja innovaatiotoiminnassa. Eroja täsmennettiin tapaustutkimusten avulla. Kohteena oli neljä yritystä, joissa tutkittiin yrityksen osaamisalueen kehittymistä keskeiseksi uudeksi liiketoiminta-alueeksi. Näistä kaksi liittyi liimapuuteollisuuteen, jossa tavoitteena oli edistää puun käyttöä rakentamisessa. Kahdessa muussa tavoitteena oli kauran jalostaminen terveysvaikutteiseksi elintarvikkeeksi. Vaikka näiden alueiden välillä on tärkeitä eroja, tapausten valinnassa otettiin ennen muuta huomioon niiden sijoittuminen OECD:n määritelmien mukaisesti perinteisten alojen matalimpaan teknologialuokkaan. Toisaalta yritykset ovat esimerkkejä pitkälle kehitetyn osaamisen ja uuden teknologian soveltamisesta perinteisessä liiketoiminnassa. Näin niiden avulla voidaan valottaa innovaatioindikaattoreiden ja varsinkin t&k-tilastojen soveltuvuutta innovaatiotoiminnan moninaisuuden kuvaamiseen.

Johtopäätökset

Sekä tilastolliset analyysit että tapaustutkimukset osoittavat selvästi, että t&k-intensiivisyys tai matala teknologia käsitteinä ovat riittämättömiä kuvaamaan perinteisten alojen osaamispohjaa tai innovaatiotoiminnan moninaisuutta. Perinteisten alojen parannusinnovaatioiden taustalla on varsin pitkälle kehittynyttä syvällistä osaamista, uusien teknologioiden taitavaa soveltamista, monimutkaisia yhteistyöverkostoja ja usein myös varsin uusia liiketoimintakonsepteja, joissa esimerkiksi informaatioteknologialla on keskeinen merkitys.

Tutkimuksen edellä mainitussa tilastollisessa osuudessa korostuvat erityisesti kilpailulliset tekijät innovaatioiden lähteinä perinteisillä aloilla. Näiden ilmentymiä tapaustutkimuksissa ovat kiristyvä hintakilpailu sekä tuotantomenetelmien jatkuva kehittäminen ja siihen liittyvät investoinnit. Kaikille tutkituille yrityksille on yhteistä tuotteiden jatkokehittäminen tuotantomenetelmiin, materiaaleihin tai raaka-aineiden ominaisuuksiin tehtävien pienten parannusten avulla. Näillä tähdätään paitsi kustannussäästöihin myös kilpailijoiden loitolla pitämiseen. Tässä kehitystyössä korostuvat pitkälle kehitetyt yhteistyösuhteet alihankkijoiden, asiakkaiden ja jälleenmyyjien kanssa. Tuotannon keskeisen merkityksen takia pääpaino yhteistyössä on tuotantoon liittyvien ongelmien ratkaisemisessa tai asiakasyhteistyön tehostamisessa perinteisesti ymmärretyn tutkimustoiminnan (t&k-toiminnan) sijasta. Tuotanto- tai asiakaskeskeisten verkostojen puitteissa syntyy täydentäviä varantoja tai riippuvuussuhteita (Teece 1986). Nämä liittyvät tyypillisesti uusien tuotteiden räätälöimiseen osaksi laajempaa järjestelmää (puurakentaminen on tästä hyvä esimerkki) tai riippuvuuteen tietyntyyppisestä raaka-aineesta tuotannossa.

Erityisen tärkeä kilpailutekijä kaikissa tutkituissa yrityksissä on tavaramerkkien kehittäminen. Tästä syystä isoilla yrityksillä on usein etulyöntiasema suhteessa tulokkaisiin. Toisaalta tuotteisiin tehtävien jatkuvien pienten parannusten taustalla on usein hyvin pitkälle kehittynyttä tuotantomenetelmällistä osaamista, joka on yleensä pikemminkin kokemusperäistä ja yrityksen sisällä syntynyttä kuin ulkoa hankittua esimerkiksi kone- ja laiteinvestointien yhteydessä. Tässä mielessä voidaan hyvinkin puhua hiljaisen kokemuspohjaisen tiedon merkityksestä, jolloin t&k-toiminta antaa selvästi liian suppean kuvan yritysten ydinosaamisesta (vrt. Rosenberg 1982; Laestadius 1998).

Vaikka teknologiset mahdollisuudet ovat rajatumpia perinteisillä aloilla, on kuitenkin selvää, että yritykset nojautuvat innovaatiotoiminnassaan myös uusiin teknologioihin sekä uusiin tieteellisiin saavutuksiin. Esimerkiksi puutuoteteollisuudessa sovelletaan laajasti informaatioteknisiä ratkaisuja tuotannossa ja markkinoinnissa. Puurakenteissa yhdistetään uusia materiaaleja. Samoin elintarviketeollisuudessa esimerkiksi biotekniikan merkitys kasvaa. Yksi perusongelma on innovaatiotoiminnan tuotantokeskeisyys kilpailutilanteen ja korkeiden kiinteiden investointien takia. Näissä puitteissa on vaikeata irrottaa resursseja täysin uusien tuotteiden kehittämiseen. Strateginen peruskysymys on aikaansaada järkevä tasapaino yhtäältä tuotantomenetelmien jatkuvan kehittämisen ja toisaalta kokonaan uusien tuotteiden luomisen välillä.

Tähän problematiikkaan liittyy myös erilaisten toimialayhteisöjen ja ammattikuntien väliset kognitiiviset kuilut, kun erilaisia teknologioita ja käytäntöjä joudutaan yhdistämään uudella tavalla. Hyvä esimerkki tästä on puurakentamisen uusien konseptien vieminen perinteiseen talonrakentamiseen. Toinen esimerkki on tiedeyhteisön integroituminen perinteiseen elintarviketuotantoon, johon tosin liittyvät myös kuluttajien erilaiset mieltymykset ja näkemykset terveysvaikutteisista elintarvikkeista tai elintarviketuotannon tieteellistymisestä laajemmin. Tutkituissa yrityksissä tämäntyyppisiä kuiluja on kurottu umpeen kehittämällä yhteistyötä yliopistojen, tutkimuslaitosten ja vastaavien sidosryhmien kanssa. Yhteistyöhön on tyypillisesti liittynyt avainhenkilöiden erikoistuminen ja samankaltainen koulutuksellinen tausta (vrt. Allenin (1977) technological gatekeepers -käsite).

Kilpailuolosuhteiden lisäksi myös lainsäädännölliset tekijät nousivat selvästi esiin tapaustutkimuksissa. Yksi haastateltava puutuoteteollisuudesta ilmaisi huolensa toteamalla, että "telealalla implementoidaan parhaillaan kolmannen sukupolven standardia...meillä ei ole ensimmäistäkään". Standardeilla voi siis myös olla ratkaiseva merkitys innovaatiotoiminnassa monilla perinteisen matalan teknologian aloilla. Esimerkiksi puurakentamiseen liittyvien standardien kehittymättömyys on yksi avainkysymys varsinkin viennin kannalta. Monet elintarviketeollisuuden alat laahaavat kehityksen perässä esimerkiksi terveysvaikutteisten elintarvikkeiden markkinointia koskevan ja muun tiukan lainsäädännön tai sen puuttumisen takia. Suotuisan kehityksen ja standardoinnin esteenä on kuitenkin usein raaka-aineiden heterogeenisyys. Esimerkiksi telealalla on helpompi räätälöidä teknologisia ratkaisuja kuin puurakentamisessa tai elintarvikkeissa, joissa syy-vaikutus -suhteiden selvittämiseen menee yleensä vuosia.

Politiikkanäkökulmat

Innovaatiopolitiikan näkökulmasta keskeiset haasteet liittyvät t&k-tukien kohdentamiseen sekä perinteisten matalan teknologian alojen yleisten toimintaedellytysten parantamiseen. T&k-toiminnan tason nostaminen perinteisillä matalan teknologian aloilla ei saa olla itseistarkoitus. Itse asiassa sekä tilastollisessa analyysissä että tapaustutkimuksissa käy selvästi ilmi, että julkisten t&k-panostusten volyymi ja merkitys on suuri myös näillä aloilla, vaikka tietynlainen polarisoituminen eri alojen välillä onkin ilmeistä ja väistämätöntä. Tärkeämpi kysymys on, missä määrin erityyppisten tukimuotojen painottamisessa kyetään ottamaan huomioon korkean ja matalan teknologian alojen innovaatiotoiminnan erilaisuus.

Tapaustutkimusten valossa on perusteltua korostaa teknologian diffuusion ja siirtämisen merkitystä varsinkin uuden teknologian varhaisissa kehitysvaiheissa, kun sovellusmahdollisuuksia on vielä runsaasti. Yksi johtopäätös tästä olisi suosia teknologiaohjelmia ja verkostoja yksittäisten t&k-tukien sijasta. Näin tavoitteena olisi selvemmin tukea geneeristen uusien teknologioiden soveltamista osana perinteisten alojen uudistumista sekä yleisemmin erilaisten toimialojen vuorovaikutusten edistämistä. Toisaalta aikaisemmin on todettu, että toimialojen ja teknologioiden väliseen yhteistyöhön liittyy myös ongelmia ja riskejä erilaisten osaamisprofiilien ja perinteiden takia. Toinen epävarmuustekijä liittyy kilpailuasetelmaan, jossa perinteisessä teollisuudessa hintakilpailun ja tuotannon merkitys korostuvat tutkimustoiminnan sijasta. Näissä oloissa voi olla vaikeata identifioida yhteisiä esikilpailullisia tutkimusalueita.

Koska perinteisillä aloilla muiden toimintojen kuin t&k-toiminnan asema korostuu, innovaatiopolitiikan olisi huomioitava myös muuntyyppiset politiikkalohkot ja toimintaedellytykset. Tärkeä kysymys on esimerkiksi koulutetun työvoiman saaminen vastaamaan perinteisten matalan teknologian alojen erityistarpeita. Informaatioteknologian korostuminen opetuslaitosten koulutusohjelmissa on myös ollut omiaan heikentämään perinteisempien ammattien imagoa ja koulutetun työvoiman saantia. Tämän takia yrityksillä saattaa olla vaikeuksia turvata perusosaamisensa jatkuva kehittyminen. Tähän liittyy myös aluetaloudellisia näkökulmia, koska esimerkiksi raaka-aineen läheisyys vaikuttaa yritysten sijoittumiseen. Samoin on tärkeätä turvata perinteisten alojen tarvitseman perustutkimuksen korkea taso ja jatkuvuus huolimatta korkean teknologian merkityksen kasvusta. Koulutuspoliittisten näkökulmien lisäksi on myös paikallaan korostaa standardisoimisen ja lainsäädännön merkitystä. Esimerkiksi puurakentamisen kannalta julkisten toimenpiteiden myötävaikutus on ollut olennaista erityisesti toiminnan alkuvaiheissa. Toinen ongelma on vientiponnistelujen tukeminen, johon usein liittyy tarve yhtenäistää lainsäädäntöä ja uusien tuotteiden hyväksymiskriteeristöjä. Tähän tarvitaan hyvää yhteistyötä kilpailuasemassa olevien yritysten kesken sekä esimerkiksi EU:n kansainvälisiä yhteistyöelimiä.

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Appendix 1

Extended tables

Sector	N	%				
		NA	1-19	20-99	100 -499	500+
All manufacturing	985	26	23	15	12	24
High R&D	115	15	22	7	5	51
Electronics, telecom	83	8	27	10	6	49
Pharmaceuticals	32	31	9	-	3	56
High-medium R&D	512	25	28	18	14	15
Instruments	122	25	36	11	16	12
Electrical equipment	59	24	25	25	19	7
Transport equipment	18	44	39	6	-	11
Chemicals	68	37	22	21	13	7
Machinery	245	20	26	20	13	20
Low-medium R&D	153	37	18	14	5	27
Petroleum refining	20	5	-	-	-	95
Non-metallic minerals	17	47	24	6	12	12
Basic metals	20	25	5	5	5	60
Metal products, ships	87	41	23	22	3	10
Other manufacturing	9	67	22	-	11	-
Low R&D	205	27	14	13	18	29
Foodstuffs	97	12	10	12	25	40
Textiles, clothing	19	32	37	5	21	5
Forestry-based	83	43	12	14	8	22
Printing & publishing	6	33	17	17	17	17

Table 2A. The size structure of innovating firms by R&D intensity.

Sector	N	%					
		NA	Other firm	<1 years	2–4 years	5–9 years	10< years
All manufacturing	988	19	16	10	12	16	27
High R&D	115	17	8	7	8	21	40
Electronics, telecom	83	11	4	10	11	28	37
Pharmaceuticals	32	31	19	–	–	3	47
High-medium R&D	515	18	16	11	14	15	25
Instruments	122	17	20	11	16	12	23
Electrical equipment	59	10	19	20	14	22	15
Transport equipment	18	22	22	22	6	6	22
Chemicals	68	24	18	12	12	13	22
Machinery	248	19	13	7	15	15	30
Low-medium R&D	153	24	22	8	15	12	20
Petroleum refining	20	15	–	–	5	35	45
Non-metallic minerals	17	29	35	12	6	6	12
Basic metals	20	5	30	–	15	15	35
Metal products, ships	87	30	20	9	20	8	14
Other manufacturing	9	22	44	22	11	–	–
Low R&D	205	17	17	10	8	17	32
Foodstuffs	97	10	9	6	7	20	47
Textiles, clothing	19	21	16	5	11	16	32
Forestry-based	83	22	28	13	8	16	13
Printing & publishing	6	33	–	33	–	–	33

Table 3A. The age structure of innovating firms by R&D intensity.

Sector	N	%				
		NA	High	High-medium	Low-medium	Low
All manufacturing	985	10	2	38	31	19
High R&D	115	13	3	70	13	1
Electronics, telecom	83	16	5	64	16	0
Pharmaceuticals	32	6	0	84	6	3
High-medium R&D	512	8	3	44	36	9
Instruments	122	8	2	72	16	2
Electrical equipment	59	12	2	54	29	3
Transport equipment	18	0	6	33	39	22
Chemicals	68	9	0	28	31	32
Machinery	245	8	4	33	49	7
Low-medium R&D	153	14	3	25	42	16
Petroleum refining	20	5	0	80	15	0
Non-metallic minerals	17	12	0	0	41	47
Basic metals	20	15	5	20	55	5
Metal products, ships	87	17	5	21	45	13
Other manufacturing	9	11	0	0	44	44
Low R&D	205	11	0	13	20	56
Foodstuffs	97	12	0	8	12	67
Textiles, clothing	19	0	0	0	26	74
Forestry-based	83	11	1	22	24	42
Printing & publishing	6	17	0	17	50	17

Table 4A. The complexity of new products by R&D intensity.

Sector	N	Viewpoint of the firm %			Viewpoint of the market %	
		Ent. New	Sign. Change	Minor change	Finnish market	Global markets
All manufacturing	569	61	34	5	24	76
High R&D	45	64	31	4	13	87
Electronics, telecom	24	58	38	4	25	75
Pharmaceuticals	21	71	24	5	0	100
High-medium R&D	327	60	35	5	21	79
Instruments	82	62	33	5	19	81
Electrical equipment	33	64	36	0	20	80
Transport equipment	12	50	42	8	56	44
Chemicals	45	64	33	2	27	73
Machinery	155	57	37	6	18	82
Low-medium R&D	90	62	36	2	20	80
Petroleum refining	9	67	33	0	22	78
Non-metallic minerals	10	80	20	0	20	80
Basic metals	14	50	50	0	29	71
Metal products, ships	49	63	35	2	17	83
Other manufacturing	8	50	38	13	14	86
Low R&D	107	64	29	7	44	56
Foodstuffs	46	65	24	11	59	41
Textiles, clothing	8	75	25	0	25	75
Forestry-based	48	56	38	6	34	66
Printing & publishing	5	100	0	0	40	60

Table 5A. Degree of novelty of new products by R&D-intensity.

Sector	N	%	
		Used in other industries	Used by more than five other industries
All manufacturing	761	57	7
KIBS	141	66	11
Software, related services	60	73	12
R&D services	61	59	5
Telecom services	8	63	63
Other business services	12	67	8
High R&D	45	51	9
Electronics, telecom	24	67	17
Pharmaceuticals	21	33	0
High-medium R&D	320	53	7
Instruments	80	58	9
Electrical equipment	31	48	19
Transport equipment	12	42	0
Chemicals	45	58	2
Machinery	152	50	5
Low-medium R&D	91	59	4
Petroleum refining	10	70	10
Non-metallic minerals	10	90	10
Basic metals	14	79	14
Metal products, ships	49	49	0
Other manufacturing	8	38	0
Low R&D	105	56	4
Foodstuffs	44	52	5
Textiles, clothing	8	38	13
Forestry-based	48	63	2
Printing & publishing	5	60	0

Table 6A. Sectoral use of new products by R&D intensity.

Sector	N	%				
		Com. of core technology	Comb. of compo-nents	Dev. of process technology	Com. of service concepts	Other types of know-ledge
All manufacturing	565	34	41	19	2	4
High R&D	45	56	33	2	2	7
Electronics, telecom	24	46	54	0	0	0
Pharmaceuticals	21	67	10	5	5	14
High-medium R&D	323	36	46	13	1	4
Instruments	81	44	42	6	0	7
Electrical equipm.	32	31	50	16	0	3
Trans. Equipment	11	18	73	9	0	0
Chemicals	45	42	24	24	0	9
Machinery	154	31	53	12	3	1
Low-medium R&D	91	29	41	25	1	4
Petroleum refining	10	40	30	20	0	10
Non-metal minerals	10	30	30	40	0	0
Basic metals	13	23	8	54	0	15
Metal products, ships	50	26	54	16	2	2
Other manuf.	8	38	38	25	0	0
Low R&D	106	25	27	39	5	4
Foodstuffs	45	24	22	40	7	7
Textiles, clothing	8	13	25	50	0	13
Forestry-based	48	27	33	38	2	0
Printing & publishing	5	40	20	20	20	0

Table 7A. Nature of knowledge input required for the development of new products by R&D-intensity.

Sector	N	%				
		Same year	1–2 years	3–5 years	6–9 years	10+ years
All manufacturing	510	6	46	31	12	6
High R&D	37	3	35	27	11	24
Electronics, telecom	22	5	50	36	5	5
Pharmaceuticals	15	0	13	13	20	53
High-medium R&D	289	4	47	31	12	6
Instruments	66	2	36	42	14	6
Electrical equipment	32	6	47	22	19	6
Transport equipment	11	18	45	18	9	9
Chemicals	43	2	44	30	14	9
Machinery	137	4	53	30	9	4
Low-medium R&D	82	9	38	38	12	4
Petroleum refining	8	0	38	38	0	25
Non-metallic minerals	9	0	44	33	22	0
Basic metals	12	17	17	42	25	0
Metal products, ships	46	9	43	35	11	2
Other manufacturing	7	14	29	57	0	0
Low R&D	102	9	56	25	10	1
Foodstuffs	45	9	58	20	13	0
Textiles, clothing	8	0	88	0	12	0
Forestry-based	45	9	49	33	7	2
Printing & publishing	4	25	50	25	0	0

Table 10A. Development times of new products by R&D intensity.

Sector	N	% Share of new products with public R&D support
All manufacturing	548	64
High R&D	45	89
Electronics, telecom	24	83
Pharmaceuticals	21	95
High-medium R&D	304	64
Instruments	66	74
Electrical equipment	33	70
Transport equipment	12	67
Chemicals	45	62
Machinery	148	60
High-medium R&D	89	73
Petroleum refining	10	70
Non-metallic minerals	9	67
Basic metals	13	70
Metal products, ships	49	76
Other manufacturing	8	75
Low R&D	110	44
Foodstuffs	47	32
Textiles, clothing	8	63
Forestry-based	50	48
Printing & publishing	5	80

Table 14A. The share of new products with public R&D support by R&D intensity.

Sector	N	% Share of new products with public programs regarded as important
All manufacturing	536	21
High R&D	44	25
Electronics, telecom	24	17
Pharmaceuticals	20	35
High-medium R&D	299	20
Instruments	65	23
Electrical equipment	33	30
Transport equipment	12	17
Chemicals	44	18
Machinery	145	17
Low-medium R&D	88	25
Petroleum refining	10	50
Non-metallic minerals	10	30
Basic metals	13	23
Metal products, ships	47	23
Other manufacturing	8	0
Low R&D	105	17
Foodstuffs	45	9
Textiles, clothing	8	25
Forestry	47	17
Printing and publishing	5	80

Table 15A. The share of new products with public programs regarded as important by R&D intensity.

Appendix 2

Interview structure

1. BACKGROUND
Personal background of the interviewees
History of the firm/division/unit
Core competence areas and main products of the firm, basis for competitiveness

2. DEVELOPMENT OF COMPETENCE AREAS / PRODUCT GROUPS
Short history of the development of the core competence areas
In-house development versus outsourcing and important collaborative partners
The application of competencies – new products, competitiveness in product area

3. DEFINING R&D VERSUS OTHER TYPES OF ACTIVITY
The definition and nature of R&D undertaken
The role of R&D versus other 'innovative activity'

4. CONTEXTUAL ISSUES – THE ENVIRONMENT OF THE FIRM
The nature and content of opportunities, generic versus specific opportunities, discontinuities, application areas
The nature of competition and the market
The appropriability of innovation – different mechanisms
The role and significance of public initiatives, policy issues

5. WHO ELSE SHOULD BE INTERVIEWED, LITERATURE SOURCES, ETC