DISSERTATIONES RERUM OECONOMICARUM
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SOURCES OF KNOWLEDGE USED IN INNOVATION: AN EXAMPLE OF ESTONIAN WOOD INDUSTRIES

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TARTU UNIVERSITY PRESS

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This dissertation is accepted for the defence of the degree of Doctor of Philosophy (in Economics) on 19 March 2008 by the Council of the Faculty of Economics and Business Administration, the University of Tartu.

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Commencement: The public defence of the dissertation is on 24th of April, 2008 at 14.00 p.m. in room 105, Lossi Str. 3, University of Tartu.

The publication of this dissertation is granted by the Faculty of Economics and Business Administration, the University of Tartu.

ISSN 1406–1309
ISBN 978–9949–11–833–5 (trükis)
ISBN 978–9949–11–834–2 (PDF)

Autoriõigus Kadri Ukrainski, 2008

Tartu Ülikooli Kirjastus
www.tyk.ee
Tellimus nr. 120

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INTRODUTION

Motivation for the research

Knowledge plays a central role in innovation and technological change as emphasized by the literature on evolutionary economics (Nelson, 1995; Dosi, 1997; Metcalfe, 1998) and also in the literature dealing with knowledge-based economy (Lundvall, 1995; Lundvall, Johnson, 1994; Cowan et al. 2000). Many authors have pointed to the growing role of knowledge and learning in the economy referring to it as the knowledge society (Drucker, 1993) or innovation-mediated production (Florida, Kenney, 1993). Economic performance depends on the speed and efficiency at which knowledge is diffused and exploited, but also at which new knowledge is created. The main claim of this literature is that the basic source of value and profit has shifted from physical labour and manual skill to the intelligence and intellectual labour whereby both, R&D specialists and workers on the factory floor are sources of ideas and continuous innovation (Florida, 2002:160). There are several theories of the firm that consider it as a response to knowledge related problems.

The different understanding of the role and flows of knowledge in the innovation processes of a firm has evolved through time from linear science-push model to an interactive model or even further to the fifth generation model (see e.g. Rothwell, 2002) held to be somewhat idealistic. The critique of the linear model was mainly shown through case studies revealing that the linearity of the innovation process has been too simplistic for explaining both sides – science and technology (Faulkner, 1994:427). Innovation is usually not a single-firm activity; it increasingly requires an active search process in order to tap new sources of knowledge and technology and apply them in products and production processes (Roelandt, den Hertog, 1999). It requires the creation of new knowledge or the combination of existing knowledge in a new way and hence is based on learning, which is largely a social process, especially by transferring and accumulating tacit knowledge (Howells, 1995). According to Lundvall (1995), interactive learning and collective entrepreneurship are both important for innovation; hence one should look at innovation as an iterative, cumulative and cooperation-based phenomenon (Freel, 2003). Innovation opportunities exist because of information asymmetry, firms that have access to a large variety of sources of information are in a better position to identify and develop innovation opportunities (Venkataraman, 1997). Therefore, Von Hippel (1988) speaks of the distributed innovation process.

Since innovation is very complex in nature, various agents and their interaction have to be taken into account when analysing this phenomenon. According to the systems approach, innovation is regarded as a system, which contains emphasis on interactions, inter-connectedness and synergies (Marinova, Phillimore, 2003: 47). In a sectoral system's view, innovation (and also production) systems are considered to be processes that involve systematic interactions among different actors for the purpose of generating and exchanging knowledge relevant for innovation and its commercialisation (Malerba, 2004: 2). Therefore, the sectoral system of innovation contains certain knowledge and technology, actors and networks and institutions. The systems of innovation approach, the literature of networks and the literature of social capital have common intersections[1].

The empirical evidence shows that sectoral innovation systems differ in terms of the patterns of innovative activities, but for each sectoral system, similarities across countries do exist (Malerba, Orsenigo, 1996). These similarities in sectoral systems stem from the features of technological regimes, knowledge base and learning processes that are relatively invariant across countries (Breschi et al., 2000). Similarities have been found in the conditions of the appropriability and cumulativeness of knowledge across countries. However the creation and exploitation of technological opportunities is not so similar in sectoral systems across countries because this is related to the level and characteristics of university research, science-industry bridging mechanisms, inter-firm networks and the types and level of innovation efforts within firms (Nelson, 1993).

This study brings together literature from several streams of research related to knowledge, innovation and management – the history of technology, the management of technology, the economics of innovation and of information, resource-based theory and organisational learning. The acquisition and use of external knowledge is currently a major issue discussed in innovation and management research; in the field of the economics of technological change, attention is being paid to the broader knowledge base firms should have for innovating; and in science and technology studies, researchers are trying to refine the conceptualisation of knowledge in innovation. The approaches to firms that are knowledge centred stem from resource-based theory (Penrose), institutional economists (Williamson), evolutionary economists (Nelson, Winter, Dosi) and epistemologists (Polanyi).

This study deals with the relevance of the different knowledge sources for innovation processes using Estonian wood sector firms as an example[2].

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[1] Although the literature on business networks and social capital is not separately discussed in this research, the ideas of the authors discussing business networks (Håkansson, Snekota, Lundvall) have been carried on to the evolutionary literature via works of Dosi and Winter; in addition some specific literature on business networks is reviewed by the discussion of specific sources of innovation. In addition, the ideas of social capital literature (Putnam, Bourdieu, Coleman) are carried on to this research via institutionalist literature (Wolfe, Gertler, Mytelka).

[2] Wood sector is comprising in this study the wood processing, pulp and paper, and furniture industries. In some empirical sections depending from the data availability, forestry is also included, but clearly, no generalisations concerning forestry can be made based on this work.

Estonian wood sector is chosen, because it is one of the most relevant traditional sectors in Estonian economy (wood is one of the very few abundant natural resources of the country). The sector has been always highly export-oriented, but the developments in recent years (shortage of raw materials and increased labour costs) have challenged the wood-related firms to seek new innovative solutions for ensuring the competitiveness in the long run.

Although the empirical section is more narrowly targeted, it allows in a broader perspective to view the contribution of individual knowledge sources used for research, design and development (RD&D) activities and to specifically compare how these different sources contribute to innovation. The novelty of the study lies in incorporating both, the content and the source of knowledge into a detailed analysis of innovation processes. This type of research has not attained systematic interest in the literature, except for two studies – Gibbons and Johnston (1974) and Faulkner et al. (1995). Both of these studies analyse the role of different public sector research sources, but the role of some business sources (e.g. competitors) is not studied. Vincenti (1990) by contrast, studies the business sources more broadly, but the methodology is not directly comparable with above-mentioned studies.

However, this kind of study is relevant for many reasons because it enables a better understanding of the movement of knowledge accompanying innovation processes within and between organisations. More specifically, it enables to analyse the innovation behaviour of firms when they must balance their short-term need for an external knowledge source against the longer term development of internal knowledge sources. In addition, the potentially different determinants of alternative types of knowledge and the simultaneity of innovation cooperation and knowledge exchange have largely remained unexplored in empirical work so far (Belderbos et al. 2004). Despite the considerable literature dedicated to the cooperative innovation activities, there are only a few that study the breadth of firm, sector and other characteristics (exceptions are Kleinknecht and Reijnen, 1992; Fritsch, Lucas, 2001; Tether, 2002). Besides the general interest on this topic, some specific sectoral aspects are perhaps even more appealing. In recent years, the innovative activities in high-tech sectors are studied and the so-called low-tech sectors have received less attention. One exception iss the PILOT[3] study, where the misuse of the term low-tech sectors was shown via the analysis of several case studies. In addition, such sectors often are quite relevant for economies; therefore the choice of Estonian wood sector seems well justified.

In this study, the knowledge used for innovation is categorised from two aspects: content and source. It is important to analyse different definitions and

[3] An EU 5th Framework Programme study "Policy and Innovation in Low-Tech Knowledge Formation, Employment & Growth Contributions of the 'Old Economy' Industries in Europe (PILOT)".

typologies or categories of knowledge in order to understand its role in innovation processes. The frequency with which a particular type (or source) of information is used is a useful indicator measuring its relative importance in innovation (Gibbons, Johnston, 1974:231). In the context of innovation, it is necessary to determine the cognitive or epistemological features of knowledge used for innovation. From the perspective of the capabilities to innovate, it is critical to determine who possesses specific knowledge and how easy or difficult it is for companies or individuals to access and make use of this knowledge (Faulkner, 1994: 426). Von Hippel (1988: 3) speaks about the 'functional source' of innovation, meaning that firms or individuals are categorised according to their functional relationship to the benefit from a specific innovation (e.g. the manufacturers, users, suppliers etc.). It has been found that the functional source of innovation varies according to the types of innovation; across sectors/technologies etc. (see Von Hippel, 1988; Pavitt, 1984). Therefore, the more thorough our understanding of knowledge is, the better we can understand what happens to it when it is transferred between and developed by different actors (individuals, firms, universities etc.) in the processes of innovation (Faulkner, 1994:426). The analysis of different sources of knowledge and their mutual complementarities or substitutability is also an important issue, because in the literature different alternative sources are traditionally handled as isolated issues (Vanhaverbeke et al. 2002).

The aim and research tasks of the thesis

The aim of this study is to use in-depth analysis of the characteristics and determinants of knowledge to identify relevant knowledge sources for innovation processes in Estonian wood sector firms. In order to achieve this aim, the following research tasks were set up:

1. to identify the content and characteristics of knowledge used for industrial innovation;
2. to identify the different sources that carry the knowledge relevant for innovation processes in firms;
3. to analyse the factors that influence the choice of knowledge sources;
4. to bring out the specific features of knowledge used in wood sector firms;
5. to develop empirical models describing the choices firms make when using different knowledge sources for innovation processes;
6. to empirically analyse the factors influencing the choice of different knowledge sources;
7. to analyse the complementarity and substitability of knowledge sources used in innovation processes;
8. based on empirical results to propose some policy recommendations.

The scope of this study is to assess the process of disseminating innovation-related knowledge in Estonian wood-based industries, but this study is more broadly about knowledge frontiers within the industrial sector and between institutional sectors, industry and academia. The broader questions raised relate to the reasons for interaction and the limits of interaction in a specific case. The factors influencing how firms choose different knowledge sources are analysed to understand the underlying multivariate structure.

This research analyses the knowledge flows from the perspective of the innovative organisation. To that end the Community Innovation Survey databases (CIS3 and CIS4) as appropriate for analysing technological innovation (Pavitt, 2005) – a driving type of innovation in those industries (perhaps less in furniture industry, where design plays more relevant role) – are used in the empirical section of the study. Then the approach that connects the content and source of knowledge is applied to analyse the knowledge flows of innovative wood sector firms. By analysing the content of knowledge, the quantification (as in Gibbons and Johnston study) can be avoided; instead the interviews with industry managers are carried out for more thorough understanding. The interviews were used for pre-selecting the hypotheses for testing. The risks of generalization from the limited number of case studies (based on interviews) are obvious; therefore both CIS 3 and CIS 4 data and the interviews are used in empirical analysis.

The study consists of two chapters, from which the first one discusses the theoretical framework (the inter-connectedness of the content, characteristics and sources of knowledge, the factors influencing the firms' choices of the knowledge sources, and mutual complementarities of knowledge sources). The chapter ends with some considerations of the sectoral specificities and distinct characteristics of the knowledge used in innovation processes of wood sector firms found in earlier literature. The empirical chapter starts with an overview of the data and methods used. Thereafter, the research hypotheses are formulated first by following the literature and subsequently, the relevant hypotheses for Estonian wood sector firms are selected for testing by using the interviews with wood sector managers as a tool for that purpose. The hypotheses are constructed for identifying the following aspects with regard to the knowledge sources used in innovation:

1. The hypotheses about the role of relevant sources of knowledge in the different stages of innovation processes;
2. The hypotheses concerning the factors influencing the choice of the relevant knowledge sources for innovation;
3. The hypotheses reflecting the complementarity (or substitutability) of the knowledge sources in the innovation processes.

In sections 2.2.2–2.2.4, the validity of hypotheses is tested. Finally, by simulating the empirical results obtained by testing the hypoteses, some policy implications are formed.

Limitations of the study

There are several empirical studies showing the complexity of innovation processes that integrating different knowledge categories, and these are summarised in following chapters. It has to be noted, however, that all the categories of knowledge summarised below do not have distinct borders, they usually overlap with some grey areas between them. Therefore the precise categorisation is not possible.

In the empirical part of this study, the knowledge sources used for innovation are assessed in terms of the subjective opinion of the representatives from each firm, and this may involve several response biases. These responses may be biased in favour of the respondent's personal opinion and organisational policy. However, when possible, the information is checked by comparing the consistency of answers from different questions[4].

The empirical part of the study does not distinguish between the channels of knowledge interaction. For example, the sources of knowledge might come from the movement of employees (between employers or from hiring graduates); however this distinction is not analysed and is classified under the internal sources of the firm. In addition, this study does not shed much light on the regional location of the knowledge sources. Some information can be used for an indirect assessment of the regional aspect, but mostly it is restricted to identifying domestic/foreign sources and in some cases even this distinction cannot be made. This is not a significant problem, because according to the interviewed managers, the knowledge exchange is in most cases has rather national dimension.

The empirical results are valid for the wood sector in its current phase of development (the period of 1998–2006 is under focus); extrapolation of the results to the future is doubtful, but also the generalisation to other countries would be difficult, because of the relevance of many relevant country-specific aspects.

Acknowledgements

This research has benefited from the discussions with and support from several people and institutions. First of all, I am grateful to my supervisors, Janno Reiljan for providing me with good research environment and Nick von Tunzelmann, whose guidance was irreplaceable during the several years of our

4 Although the consistency of knowledge sources measurement has not been studied, the consistency of subjective measurement (comparable measurement methodology as in current study) of product and process innovation has been verified by several studies (Huiban, Boushina, 1998; Romijn, Albaladejo, 2002).

cooperation. I'm also very grateful to Urmas Varblane for continuous supervision, encouragement and involvement in many research projects, which have guided me to this topic. I have benefited a lot from close cooperation and discussions with several other colleagues – Jaan Masso, Tõnu Roolaht, Tiia Vissak, Peter Friedrich, Tõnis Mets, Katrin Tamm, Ele Reiljan from University of Tartu and Dorel Tamm and Marek Tiits from Institute of Baltic Studies. The discussions with partners from the international cooperation project "U-Know" were extremely helpful in the research of innovation, and COST E51 for a better understanding of the specifics of forest industries. I have learned a lot from the interviews with industry managers by conducting the ERIS project and so I am very grateful to Vahur Käärik, Gert Rahnel, Indrek Laul, Kurt Jespersgaard, Jüri Külvik, Ivar Dembovski, Andres Alamets, Tiit Kolk, Lilian Niitsoo, Meelis Mälberg, Tarmu Ossip, Ville Timmi, Ago Soomre, Andrus Ilumets, Sven Mats, Kaido Toome, Kalle Kruus, Toomas Pertel, Ülo Viilup, Argo Mehide and Ando Jukk.

There are many colleagues in the FEBA (Mare Friedrich, Juta Freiberg, Heili Kase and many others) who have supported me during my studies – I am very grateful to them all.

There are several courses I specifically benefited from for this research during my studies. For the empirical analysis the *Discrete Choice Analysis: Predicting Demand and Market Shares* (by Prof. Moshe Ben-Akiva, Prof. Michel Bierlaire, Prof. Denis Bolduc and Prof. Daniel McFadden) was extremely useful and the *Constructing Opportunities for Research Contribution* (by Prof. Ali Yakhlef) contributed a lot to my skills of scientific writing.

The financial support from the FEBA, several research grants (ESF Grants No. 6853, 6493, 5709, 5840), but also the Target Financing Projects SF0180037s08 and TMJRI0107 have enabled to perform this research as did EU 6th Framework Program Projects "Understanding the Relationship between Knowledge and Competitiveness in the Enlarging EU" No. CIT5–028519 and "Estonian Regional Innovation Strategy" No. 014670.

Finally, I am very grateful to my family for their patience, encouragement and support during the whole period of my doctoral studies.

Naturally, all possible mistakes and errors are the sole responsibility of the author.

1. CATEGORIES AND SOURCES OF KNOWLEDGE USED IN THE INNOVATION ACTIVITIES OF THE FIRM

1.1. Categories of knowledge used in innovation

1.1.1. Theories dealing with the firm, knowledge and innovation: Basic concepts

Defining knowledge

There is a variety of literature defining knowledge as an object, a process, a state of mind or a capability. Although this study considers the knowledge in its broadest definition encompassing factual knowledge, skills and experience, for a better understanding of the role of knowledge in the innovation processes of a firm, it is important to review the typology and different concepts of knowledge.

According to Cooley (1987:11), knowledge is hierarchically driven from data and information. Suitably organised and acted upon data becomes information, which again, if absorbed, understood and applied by people, becomes knowledge. If frequently applied in a domain, knowledge becomes wisdom and wisdom forms the basis for action. This can be considered the kind of general hierarchical view of knowledge held with some small differences by Dretske (1982) and Machlup (1980). Information is hence understood as a commodity capable of yielding knowledge, one can learn from information; knowledge involves the information-produced (or sustained) belief (Dretske, 1982: 44, 86). Information contains (following Machlup) a flow of messages that can add to, restructure or change knowledge. Though "tight coupling" and the line of causation from information to knowledge is generally accepted, it is criticised mainly on two points: (1) in some circumstances (e.g. incomplete information) the information and knowledge may be loosely coupled or even uncoupled (meaning that different agents can derive different or even contradictory knowledge from the same information) and (2) the nature of information differs because it is based on a closed set of data while knowledge is open-ended (Fransman, 1998:149–151).

Other types of categorisations of knowledge relate to the object of knowledge – for example, Ryle (1949) contrasted "knowing how" and "knowing that", where "that" refers to factual knowledge and "how" to knowledge about how to perform certain activities. Although this kind of distinction is problematic it is important for determining the nature of knowing how to perform certain tasks in the meaning of skills or capabilities (Snowdon, 2003). Skill is understood as "*…a capability for a smooth sequence of coordinated behaviour* *that is ordinarily effective relative to its objectives, given the context in which it normally occurs*." (Nelson, Winter, 1982:73).

Knowledge can be held individually or collectively (Nonaka, 1994). Dosi (1988:1126) defines the term *knowledge base* following Nelson and Winter (1982) as the "*set of information inputs, knowledge, and capabilities that inventors draw on when looking for the innovative solutions*". Collectively held knowledge in the theories of firms looks at firms as repositories of knowledge or as a response to information-related problems (detailed review is given in Fransman, 1998). Fransman (1998:148–149) grouped the theories of firms into two. The first group of theories are associated with the costs of asymmetric information, opportunism and bounded rationality referring to the works of Alchian and Demsetz, Jensen and Meckling, and Coase and Williamson; and the second group looks at the firm as a repository of knowledge referring to the works of Nelson, Winter, Pernose, Chandler, Teece. This dichotomy is also used in the following discussion.

Knowledge according to the theories of the firm: microeconomic theory, economics of information and the firm as a nexus of contracts for information related problems

Microeconomic theory is founded on the assumption of rational choices made by individual agents about acquiring and processing information. There is some agreement that some characteristics of information are by nature a public good (non-rivalry and non-excludability), a market failure the extent of which is still under discussion. The distinction between knowledge and information as well as the distinction between different sources of informations is not relevant for microeconomic theory; it is regarded as a production input whereby the decision is made on the bases of price/cost. The standard theory does not deal with the specific categories and sources of knowledge by treating them mutually substitutable.

The strand of microeconomics, namely the economics of information, recognises that information is imperfect, that obtaining it may be costly and that there are important asymmetries of information depending on the actions of firms and individuals (Stiglitz 2000:1441). This strand has "*gone beyond simply destroying old results; it has provided explanations for phenomena and institutions for which the standard theory provides no explanations – and in some cases are even hard to reconcile with standard perfect information models*" (Ibid. p.1470). In this group of theories, the firm is seen as a contracting entity over joint inputs (including information), whereby the related costs are lower than productivity rewards (joint team production based on Alchian and Demsetz (1972)), or a contract between principal and agent not only within a joint team of production, but also with suppliers, customers, creditors etc. (Jensen and Meckling, 1976: 8). Coase (1937, 1988) considered that it is profitable to establish a firm, because some coordination costs are lower within the firm compared to the market. These costs involve the costs of "organizing" production through the market mechanism, the costs of negotiating and concluding separate contracts for each exchange (1937:390–391), but also asset specificity (1988:13). Williamson adds to the aforementioned model the behavioural assumptions of bounded rationality[5] and opportunism, which add some more reality and distinguish the approach from neoclassical economics (Williamson, 1981: 553).

Transactions involving costs and uncertainty between firms and external organisations are important when one considers knowledge transfer and learning. Market systems are expected to compensate for this uncertainty via the law of large numbers with highly substitutable products or factors in the conditions of perfect competition or by authority (Williamson, 1981). However, as discussed by Storper (2002:138), the learning relations do not involve large numbers because they involve development and interpretation of information, which is not fully codified and therefore not fully transmittable, understandable and utilisable independent of the agents who are developing and using it. Hence, the transaction becomes a concrete relation that cannot be abstracted from its existence as a relation.

As in this strand of literature, the character and role of different knowledge types is not elaborated, the concept of knowledge remains at a very general level as a production input only incorporating cost/price characteristics. Therefore, the different types of knowledge are mutually substitutable and can be absorbed from all kinds of different sources (internal and external) without further elaboration, except for the notion of a bounded choice set. It is also common to leave some of the knowledge embodied in artefacts as a residual or unexplained part of the production function.

The Firm as a Repository of Knowledge

As claimed by Fransman (1988:169), the evolutionary theory from Nelson and Winter (1982) emerged out of an interest in analysing the relationship between technical change and economic growth in which the inter-firm differences matter. Since individuals are bounded in their decisions, firms use decision rules and procedures to guide their actions, and these routines explain the behaviour of firms (Nelson, Winter, 1982: 128). In their approach, the firm becomes a repository of knowledge, which is contingent on the firm's past (on routines where knowledge is stored) and what makes one firm different from another (Fransman, 1998:171). The firm searches through a variety of alternatives for problem-solving activities and selects them according to its routines.

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[5] In Simon's concept of criticising the standard assumption of neoclassical theory incorporating rational decision behaviour, instead of "optimizing man", Simon found "satisfycing man" to be more realistic in describing the decision processes (Simon, 1955; Simon, 1978).

The similarity can be seen with the preceding theory from Penrose (1959), who sees the firm as a collection of productive resources rendering services, which are specific to each firm depending on the accumulated knowledge within the firm (p. 25). These services are used for productive activities following the changing productive opportunities the firm sees given its resources. As Teece, Pisano and Shuen (1990:13) conclude: "*The resource-based approach sees firms with superior capabilities and/or organisational structures being profitable not because they raise prices above long-run costs, but because they have markedly lower costs, or offer markedly higher quality of product performance*." This emerging capabilities approach tries to overcome the inability of traditional static models to explain the dynamic behaviour of firms (Von Tunzelmann, Wang, 2007:192–193). This approach combines the theory from Penrose with a similar model for consumption by Sen (1985) incorporating the characteristics of goods, the individual capabilities of the consumer[6] to use or consume them and the utility obtained from both, and how the characteristics of goods respond to the needs of the consumer (*functionings*) and from the set of capabilities to use or obtain utility from the goods (*capabilities*). Of course, the capabilities can be improved by obtaining skills to use new products or technologies. Similarly, the firms have product possibilities, production capabilities and profitability (or appropriability) with regard to production in general, but the model can be narrowed down to describe the capabilities in technology, whereby the process of creation of technology can be separated from the production process (Von Tunzelmann, Wang, 1997: 197–199). Chandler (1990) speaks about *accumulated dynamic capabilities* during the existence of the firm and their relevance in exploiting technological opportunities or competitive advantages. The capabilities of firms are aligned with the circumstances where specific firm is operating in real time (*dynamic competition* from Schumpeter) and with the respective learning mechanisms termed *dynamic interactive capabilities* (Von Tunzelmann, Wang, 2007: 202). This concept of dynamic capabilities explains the extent to which the capabilities of firms are appropriate to the environment, and to the capabilities of consumers. Therefore, it amalgamates the resource-based theory of the firm and strategic management theories (as Porter, for instance) (Von Tulnzelmann, Wang, 2007: 203).

Innovation as an outcome of knowledge production

Innovation is not a recently conceptualised phenomenon; the concept was originally formed by Schumpeter in 1911 (and in a somewhat revised version published in English in 1934). This concept, also generally accepted today,

[6] There are altogether ten types of capabilities identified (life; bodily health; bodily integrity; senses, imagination, thought; emotions; practical reason; affiliation; other species; play; control over one's environment).

considers innovation *as the introduction of a new good or of a new quality of a good, the introduction of a new method of production (including a new commercialisation method), the opening of a new market (new from the firm's perspective), the conquest of a new source of supply of raw materials or half-manufactured goods, carrying out of the new organisation of any industry* (Schumpeter, 1934: 66). In contemporary literature, it is common to classify innovations in two broader categories of product (or service) and process innovation. In addition, several sub-categories can be attributed to the latter depending on the processes developed (see also Oslo Manual (OECD, 1997) for more detailed classification and measurement issues).

It is very important to distinguish between the terms innovation and invention. An invention is the first occurrence of an idea or product or process, but an innovation is the first attempt to carry it out in practice, thereby both phenomena can be closely linked, but also separated by a considerable time lag (Fragerberg, 2005). Following Shupeterian ideas, the innovations can be regarded as ranging from an incremental or a minor novelty in products or processes to radical (also revolutionary) innovations.

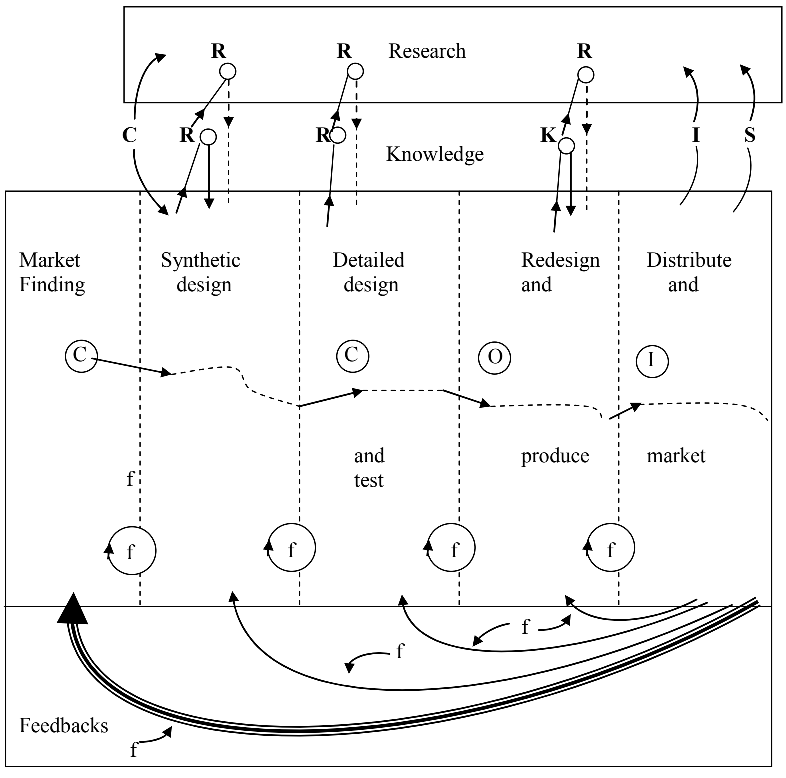
Incremental changes (also termed as normal technology by historians of technology e.g. Constant (1980)) refer to normal technological activities in firms improving the accepted tradition or its application under new or more stringent conditions. The knowledge for such activities may entail novelty and invention to a considerable degree, but it is not essentially identified by the originality of the idea as in the case of a radical innovation, and changes in technology are incremental rather than essential (Vincenti, 1990:8). Much of the radical innovations in products or processes can be the cumulative result of many minor or incremental changes, where the inventors cannot often even recall the occurrence and source very reliably (Von Hippel, 1998: 26). However, the knowledge needed for those incremental innovations can be extremely complex and diverse (Vincenti 1990:9). Of course, both types of innovation cannot be sharply separated; there are cases, where the distinction is difficult to make (Vincenti, 1990:8).

According to Dosi (1988: 1120), economic agents are allocating resources for the exploration and development of new products and new production or organisational processes if they:

a) know or believe in the existence of some sort of unexploited scientific and technical opportunities;
b) expect that there will be a market for such new products or processes and,
c) expect some economic net benefit from such innovations.

This can be useful in the context of the current analysis, as brought out by Von Hippel (1988:5), when certain preconditions are met. First, the innovating firms cannot shift their functional roles easily. Second, they benefit from the innovation themselves rather than by licensing them to others. Third, the expectations from the innovation-related rents must differ significantly between firms in different functional relationships to a given innovation opportunity. The only dangers that rents from innovations might be captured by competitors are seen in resource-based theory in the imitation or substitution of knowledge from the competitors.

There are two approaches to analysing science and technology and the knowledge that is used or produced: one focuses on science-technology distinction and one focuses on industrial innovation (Faulkner, 1994:425). Historians of technology see technology as an autonomous body of knowledge separate from science with which it interacts (Vincenti, 1990:3–4), and shifts in the knowledge of practitioners plays a crucial role in technological development (Laudan, 1984).



Link I = the supply of instruments from the manufacturing sector for use in scientific research
Link S = the support of fundamental science in the research laboratories of industrial corporations
Link C = the 2-way flow of ideas between scientific research and synthetic design
Links K and R = links to knowledge and research utilised in innovations
C-C-O-I = central chain of innovation
F and f = feedback loops for flow of information

Figure 1. The chain-linked model of innovation (Kline 1991:477)

The second model of science and technology (after the linear science push or market pull models, the “two-stream” model) relies more on empirical evidence, claiming that science tends to build on earlier science (knowledge) and technology tends to build on older technology (knowledge), but the two are weakly related and the interaction between them (mainly through literature) occurs with significant time lag (de Solla Price, 1965). The latter the model was revised in the sense that science and technology interacts through techniques and equipment needed for scientific research (de Solla Price 1984). More recent bibliometric studies reveal that in some technological fields, the interaction of science and technology has a very short time lag – the fields are strongly connected with science (this concerns e.g. biotechnology). (See Carpenter, Cooper, Narin, 1980; Carpenter, Narin, Woolfe, 1981; Narin, Noma, 1985).

Considering the processes of innovation, understanding has advanced from the linear (science-push or market-pull) innovation models to the interactive models (see Figure 1). The interactive model sees research as storage for the technical knowledge that has been accumulated over time (including both, the knowledge of researchers and their experience, but also the scientific knowledge produced in firms). Even if it is hard to precisely distinguish the borders of science and technology, Vincenti finds that the knowledge of instruments and of scientific problems posed by engineering devices flows from the engineering side to the sciemtific (1990:228). However, experimental and theoretical research in both engineering and science are often most effective when done in close proximity. “*Though they need to be distinguished for epistemological analysis, they are best pursued in actuality when minimum distinction is made between them.* “ (Vincenti 1990:232).

Innovative activities are hence, closely related to learning whereby ‘*the process by which consensual knowledge is used to specify causal relationships in new ways*’ is understood (Haas, 1990:24). Learning occurs when the organisation members question the course of action they have been pursuing and consider alternatives. In international organisations, the learning processes may be facilitated by epistemic communities – ‘*a network of professionals with recognised expertise and competence in a particular domain or issue area’* (Haas, 1992:3).

The learning process is conducted through various channels the taxonomy of which is mapped by Malerba (1992). Malerba identifies six learning types related to specific sources and types of knowledge (1992:848):

(1) learning by doing (this process is internal to the firm and according to Malerba, mainly related to the production activities);
(2) learning by using (this process is also internal to the firm and related to the use of input materials, machinery and products);
(3) learning from advances in science and technology (this is learning from external sources, absorption of new knowledge from science and technology);

(4) learning from inter-industry spillovers (this is learning from external sources such as competitors or other firms in the industry);
(5) learning by interacting (this is learning from external sources such as customers or suppliers (up- or downstream knowledge sources);
(6) learning by searching (this process is internal to the firm and related to the activities aimed at generating new knowledge, such as R,D&D).

The interactive model highlights the importance of knowledge flows between external and internal knowledge reservoirs at every point along the innovation chain, whereby learning arises from specific activities and knowledge sources.

1.1.2. General categories of knowledge used in innovation

Review of Studies for a Broad Categorisation
The broader categories of knowledge have been of interest for evolutionary economists (Nelson, Winter, Dosi and others) who distinguish knowledge categories according to the features of technological knowledge and the ease of knowledge transfer and the tradability of knowledge between the firms (Faulkner et al. 1995: 215). These categories are summarised in Appendix 1 and the categories on the right side of the table represent those that are more easily transfered. However, that is not the only way to categorise the knowledge used for innovation: Ryle (1949), Lundvall and Johnson (1994) categorise the knowledge used in innovation in terms of knowing what, knowing why, knowing how and knowing who (see Appendix 1) depending on the objects of knowledge.

Fleck and Tierney (1991) approach this from the perspective of the "social shaping of technology" and analyse technical expertise[7] in terms of knowledge and power. Hence, they conceptualise knowledge in terms of the socio-cognitive structures that relate the content of the knowledge to its distribution among actors (individuals and organisations) – the specific embodiment of knowledge. In addition to the categories (or "components", as they call them) of knowledge, shown in Appendix 1, they add a second dimension to the distribution of knowledge among individuals or carrier groups in specific social, political and economic contexts. These carrier groups are in power relationships with each other, but they also depend on the organisational and sectoral structures they work within and the technologies they use (Fleck, Tierney, 1991:4). The socio-

[7] Fleck and Tierney (1991) use the term expertise to stress that the knowledge is carried by the interest groups rather than being located in one individual. They define expertise as being „*situated, embodied and continually renegotiated in collectivities of people. It can be represented by the intersection of individual career trajectories with institutional structures such as professional affiliations and specialist technical commitments."* (Fleck, Tierney, 1991: 4).

cognitive structure of knowledge will differ according to the technical development and the power-relationships of those involved in using and supplying the knowledge.

Vincenti further divides the explicit knowledge used in design engineering into two general categories: descriptive and prescriptive, where the categories proposed by Winter, Dosi and Vincenti relate to the following form shown in Figure 2. Although descriptive and prescriptive knowledge are categories of explicit knowledge, some prescriptive knowledge is more tacit by character because it is closely related to practice and procedures. In reality, the distinctions in the figure below are not as sharp and discontinuous as they appear, but this a useful framework for looking at the substantive structure of technological knowledge (Vincenti 1990: 198).

Typically, technological innovation involves solution to problems that are "ill-structured" in the sense that the available knowledge does not provide a solution to the problem or an algorithm for how to solve the problem (Dosi, 1988:1126). The solution involves the use of previous knowledge existing in the firm (including both, tacit and codified type).

<table>
<tr><td colspan="2">Explicit knowledge</td><td></td></tr>
<tr><td>Descriptive knowledge</td><td>Prescriptive knowledge</td><td>Tacit knowledge</td></tr>
<tr><td></td><td colspan="2">Procedural knowledge</td></tr>
</table>

Figure 2. Engineering knowledge by Vincenti 1990:198.

Categories of Knowledge

The original definition of tacit knowledge stems from Polanyi (1966:4): "*We know more than we can tell",* while a more elaborate explanation comes from Rosenberg (1982:143): tacit knowledge is the knowledge of techniques, methods and designs working in specific ways with specific outcomes, but nobody can explain why exactly. Nonaka (1994:16) further distinguishes two elements of tacit knowledge: cognitive and technical. The first element is centred on mental maps, beliefs, paradigms and viewpoints and the second one on specific know-how, crafts and skills.

The tacit-type of knowledge is mainly associated with idiosyncrasy and personal experience, but can be shared to a significant degree by collaborators or colleagues who share a common experience (Dosi, 1988:1126). For example, Faulkner et al. (1995: 203) by studying the role of different internal and external knowledge sources in the firm for innovation activities found that tacit knowledge was acquired from both, internal and external sources. This absorption process differs from obtaining codified knowledge in terms of the channels used to gain the knowledge – while this kind of knowledge cannot be codified it can be exchanged by experience or example (embodied in a person), and therefore, it must involve personal interaction or personal movement (Faulkner et al. 1995:203). The dichotomy tacit vs. explicit, but also articulate vs. non-articulate from the evolutionary economists overlaps with the dichotomy informal vs. formal knowledge presented by Fleck and Tierney, but also the category of "knowing how" by Ryle, Lundvall and Johnson represents the content of tacit knowedge. It is misleading to characterise this type of knowledge as practical rather than theoretical, because it is experience-based and can apply in practical as well as theoretical problem-solving (Lundvall, 2004) and can also be sourced from academia (Faulkner et al. 1995).

The dichotomy articulate vs. non articulate and teachable and non-teachable has been further elaborated by Winter (1987) by focusing on skills that are teachable, but not articulable, and articulable knowledge that is lost because it is never articulated (like the failure in software to fully document the programming code) (Faulkner et al. 1995:216). The discussion of general vs. specific knowledge has been extended to the level of knowledge bases in different technologies (sectors) with regard to how public or universal versus how specific the knowledge bases are (Winter, 1984). Some sectors are even found to rely more on codified (or public) knowledge, this type of knowledge is found to be complementary to more specific and tacit knowledge generated within firms (Gibbons, Johnston, 1974; Pavitt, 1984). This variety of different degrees of the tacitness and specificity of the knowledge used in innovation processes helps to explain the differences in the organisation of research activities (Dosi, 1988: 1127). As the knowledge used in innovation processes is "… strongly *selective, finalised* in quite precise directions, *cumulative* in the acquisition of problem-solving capabilities", these processes follow the specific technological trajectory within the economic and technological possibilities defined by the technological paradigm (Dosi, 1988: 1128). The categories of general knowledge and meta-level knowledge overlap as do specific and contingent, but also milieu knowledge categories. The categories of system-quality (complex) vs. stand alone (simple) represent the different degrees of the complexity of the accessibility of knowledge as does the observable in use or not categorisation influenced by the capability and willingness of both, sender and recipient (Faulkner et al. 1995:216).

The first category presented by Ryle, Lundvall and Johnston, knowing facts, can be collected to the databases; however, this is far from perfect because often one needs to also come through the *knowing who* channel, in order to find a specific piece of information (Lundvall, 2004). The *knowing why* category reveals some similar characteristics because it rests on the theoretical models that scientists construct about nature. This is public in the sense that most of it is relatively freely available; however, access to it is a long process of learning, and also through the *know who* channel (Lundvall 2004). Lundvall (2004) admits that technological solutions are sometimes ahead of academic *know why*. *Know how* is the category with most limited public access and is the most difficult to transfer, because it cannot be separated from the person or research team. *Know who* is related to both the knowledge and its carrier groups or individuals within such groups. Here, the institutions such as trust are of major importance.

As many of these categories are related to *knowing who*, Lundvall (1988) argues that a common cultural background and language facilitates the transfer of tacit knowledge and effective and detailed communication that is crucial for the success of user-producer interaction. Lundvall (1988:355): '*In the absence of generally accepted standards and codes able to transmit information, face-to-face contact and a common cultural background might become of decisive importance for the information exchange*.' Hence, a common culture and background facilitate interactive learning (Lundvall, Johnson, 1994; Morgan, 1996).

Although the literature of general categorisations of knowledge used in innovation does not focus on specific sources related to specific categories of knowledge, the connections shown in Table 1 can be drawn based on the literature reviewed above.

Table 1. General Categories of Knowledge and Respective Sources of Knowledge

Category of knowledge	Main Sources of Knowledge			
	Personal	Internal	Other firms	Public sector
Tacit (implicit), nonteachable, nonarticulable, system-quality, nonobservable in use, complex, specific knowledge	Critical	Important	Difficult to transfer	Difficult to transfer
Explicit, teachable , articulable, stand alone, observable in use, simple, general knowledge	Important	Important	Important	Important
Metaknowledge	Important	Important	–	Literature
Milieu	Important	Important	Local networks	Local networks
Contingent knowledge	Critical	Important	Important	Important
Tacit knowledge	Critical	Important	Important	Training and apprenticeship
Informal knowledge	Critical	Important	Manuals, guide-books, experiments	Guidebooks, Experiments
Formal knowledge	Important	–	–	Textbooks, handbooks
Instrumentalities	Important	Important	Important	Important
Know what	Important	Important	–	Databases
Know why	Critical	Important	–	Academicians, journals
Know how	Critical	Important	Consultants, experts, cooperation activities	Experts, Cooperation activities
Know who	Important	Important	–	–

From Table 1, one can conclude that the personal and internal sources of the firm are important for any type of knowledge. Although the transfer of some categories of knowledge is difficult, it is possible when both parties are willing and share a similar experience and background. In the case of easily transferable knowledge, external sources become more relevant; however, there is still a need for personal knowledge from the recipients side and hence, again the personal and internal sources of the firm are significant.

1.1.3. Object-specific categories of knowledge used in innovation

Review of studies

In contrast to the general categories of knowledge used in innovation, detailed categories of knowledge are not as broadly discussed in the literature. There can be three in-depth studies considered in that field: Gibbons and Johnston (1974), Vincenti (1991) and Faulkner et al. (1995).

Gibbons and Johnston (1974) studied 30 award-winning innovations from different sectors[8] in early 1970s and identified in total 887 units of scientific and technological information that led to those innovations. They categorised the knowledge used for innovation according to the content of the information and the source of the information. Vincenti (1991) approaches knowledge categories from the perspective of the history of technology using detailed case studies of aeronautical engineering from the period 1900–1950. He develops an epistemology of engineering by relating the categories of knowledge to knowledge-generating activities aiming to analyse the knowledge used in the process of "normal engineering"[9], which in reality encompasses more incremental, but sometimes also radical innovations. Faulkner et al. (1995) approach this from the tradition of innovation studies with the aim of assessing the extent and character of knowledge flows from public sector research to industrial innovation, but they actually investigate a broader range of knowledge inputs to innovation on the basis of category and source. All three studies cover different sectors and different periods, but as also their authors find, the studies are commensurable. Although Vincenti's study concentrates on aeronautics, the results are more universal and can be extended to other branches of engineering (chemical and mechanical) without fundamental changes, albeit with different relative intensity (Vincenti 1991: 200, 236).

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[8] See more detailed review in Appendix 3.

[9] Vincenti defines engineers as the ones who organise, design, construct and operate artifacts that transform the physical world to meet a recognised need.

Categories of knowledge

Faulkner (1994:449–450) proposes following taxonomic axes for categorising knowledge:

1) Type of knowledge (detailed category of knowledge);
2) The object (natural world, design practice, experimental R&D, and the final product and knowledge itself);
3) Broad character of knowledge (understanding-information-skill; tacit-articulated; complex-simple; local-universal; specific/contingent-general/meta-level).

The latter two dimensions also relate to social issues and power (discussed by Fleck and Tierney) and reflect who possesses the respective knowledge and how easy or difficult it is to access it.

All the categories are summarised in Appendix 2. Before discussing the categories in-depth, one has to note that within the categories, the knowledge can also be hierarchically structured (e.g. according to the hierarchy of engineering design processes), and engineers, according to the problem solving, move hierarchically up and down within the categories as well as back and fourth between the categories) (Vincenti 1991:223). Different knowledge categories and the activities that generate them are not mutually exclusive; an item of knowledge can belong to more than one category and such overlapping categories of knowledge and simultaneous generating activities are not unusual and emerge because of the complexity of the social processes of knowledge generation and use (Vincenti, 1991:235; Faulkner, 1994:449). The different categories of knowledge interact in a specific innovation project, and different knowledge sources can be used to obtain respective categories. In the following, the discussion of the categories of knowledge is structured according to the composite typology of Faulkner et al. 1995 (see Table 2.).

The knowledge categories that relate to the natural world include *scientific and engineering theory* ("laws" of nature; theoretical tools) and the properties of materials (natural and artificial materials). The first category, overlapping with Vincenti's category of theoretical tools, is used as a basis for engineering experimentation with new products and processes (Faulkner et al. 1995), but when limited to specific devises, these theories describe the mathematical feasibility of some approximation specific to a device (Vincenti, 1991). Intellectual concepts are needed for qualitative conceptualising and reasoning before starting on quantitative activities. This category of knowledge contributes about 8% of the total knowledge used in innovative activities and is in great part obtained from external sources (from literature, universities and public sector research institutions), but also from personal (28.5%, obtained from field trials) and internal sources (22.5%) (Gibbons and Johnston, 1974).

Table 2. Detailed Categories of Knowledge and Respective Sources

Category of knowledge (% from the total units)	Main Sources of Knowledge (% from the units in respective category of knowledge)			
	Personal	Internal	Other firms	Public sector
Related to the natural world:				
Scientific and engineering theory (8%),	28.5% (field trials)	22.5%	49.3%	
			–	Scientific literature, (Universities) (GJ)
Properties of materials (32.5%)	20.1%	49.3%	30.6%	
			Users (V) (Suppliers (GJ))	Scientific and trade literature, (Research associations) (GJ)
Related to design practice:				
Design criteria and applications, design concepts, design instrumentalities* (13.9%)	40.7%	32.5%	26.8%	
			Users (V) Suppliers (GJ) Competitors (V)	(Research associations, Literature) (GJ)
Design competence* Practical experience (9.9%)	52.3%	33%	14.8%	
			Users, Suppliers, Consultants (GJ)	Literature (GJ)
Related to experimental R&D				
Experimental and test procedures, research instrumentalities*, research competence*, experimental and test data (10%)	50.6%	19.1%	30.3%	
			(Suppliers) (GJ) (Consultants) (GJ)	Hand- and textbooks (GJ)
Related to the final product				
New product ideas Operating performance Production competence*	Important	Important	Users (F) Suppliers (F)	
	Pilot production, direct trials (F)			
Related to knowledge:				
Existence and availability of materials and components (13.9%)	38.2%	8.9%	52.8%	
			Suppliers (GJ)	Hand- and textbooks (GJ)
Existence of specialist facilities and services (3%)	14.8%	14.8%	70.4%	
			(Suppliers) (GJ)	Universities (GJ)
Location of knowledge (8.8%)	64.1%	10.3%	25.6%	
			(Suppliers) (GJ)	Universities (GJ)

Source: Author's compilation of Gibbons, Johnston (GJ) (1974), Vincenti (V) (1990) and Faulkner et al (F) (1995). All numerical results are from the study of Gibbons and Johnston.

The category of the *properties, composition and characteristics of materials and components* comprises information that describes the make-up and performance of both natural and man-made objects useful in the new products (Gibbons, Johnston, 1974). This category overlaps with Vincenti's category of criteria and specifications that are the general qualitative goals of the device or technology translated into specific quantitative and concrete technical terms. In more general circumstances, these technical specifications can apply across an entire technology (Vincenti, 1991). This is the most frequently used category of knowledge in innovation (32.5% of units) (Gibbons, Johnston, 1974). From among the various sources, 20.1% are personal, 49.3% internal and 30.6% external. Personal knowledge of technical criteria appropriate to the device and its use, but also knowledge of its limitations are necessary – stemming from general engineering education, experience of the specific device, internal sources or design practice and direct trials (including operation) (Vincenti, 1991). From among external sources, the scientific and trade literature, but also research institutions (theoretical engineering research, experimental engineering research) are relevant (Gibbons, Johnston, 1974; Vincenti, 1990). There are slightly different views of the relative importance of users and suppliers – Vincenti finds users to be more important while Gibbons and Johnston find suppliers to be a slightly more relevant source of this kind of knowledge. However, this difference might also stem from the different types of innovation that firms undertake.

The knowledge related to design practice involves design criteria and applications (understanding user requirements; the demands of company and technology; the specifications of the components), design concepts (fundamental operation principles; normal configurations; creative ideas), design instrumentalities, design competence (general design competence; competence in specific product areas) and practical experience.

Design criteria are drawn up on the basis of the dual requirements of companies and potential users. *Detailed specifications* are produced by following more technical considerations, feasibility etc. Alternative concept designs are considered and one is eventually selected, thereafter the detailed design of the product is elaborated (Faulkner et al. 1995). Design-based information resulting from the analysis of the required or appropriate design, such as particular performance characteristics or necessary materials comprises about 13.9% of the units of knowledge used for innovation, 40.7% stems from personal, 32.5% from internal and 26.8% from external sources (Gibbons, Johnston, 1974). According to Vincenti, extensive user-engineer communication and mutual learning is often needed for user knowledge to be incorporated into the design specifications of a product. However, this might take quite a long time (a 25 year period of close interaction in the example of the tacit knowledge transferred from pilots into codified flying quality specifications) (Vincenti, 1990: 239). Knowledge in different categories (most strongly in fundamental design concepts and criteria and specifications) is influenced by the demands of users, but also by interactions between various social groups (Vincenti, 1990:228). Gibbons and Johnston's study finds that suppliers are more important, but so also are research institutions, since they are not analysing the role of competitors separately. However, communities of engineers in different firms compete and this enhances the motivation for taking up difficult problems; at the same time, their cooperation offers support in overcoming difficulties. The interchange of knowledge and experience fosters the generation of new knowledge, which once generated becomes disseminated by word of mouth, teaching and publication and in this way, incorporated into the community's tradition of practice (Vincenti, 1990:239).

The category of *design instrumentalities* encompasses procedures, ways of thinking and the judgmental skills required in the process of designing a device, but also seeking solutions where some degree of novelty is required. The procedures of engineering problem-solving are more satisfiying, less formal and demand more judgmental skills than optimising procedures (Vincenti, 1991). Judgmental skills, which are mostly tacit, are very important (visual thinking, insight, imagination, intuition, the feeling for elegance and aesthetics in technical design), and these are learned through practical experience. With regard to the sources, those skills are more personal, although they are shared to some extent between designers (Vincenti, 1991).

An additional category, overlapping considerably with the previous one, is *design competence* (Faulkner et al. 1995) or *practical considerations* (Vincenti, 1991). This category encompasses considerations that are derived from practice and are not codifiable (and are sometimes more or less unconscious to the engineer or designer) – so-called rules of thumb. In the longer term, if they become precise enough, some of them may be codified (and move to the category of quantitative data) (Vincenti 1991). This knowledge is mainly drawn from personal sources. The role of competences and skills (both, general and specific) is highly relevant in all aspects of design (Faulkner et al 1995). From the categories of Gibbons and Johnston, *operating principles* can be considered here, although these encompass wider activities than only design activities. Operating principles include 'rules of thumb', the properties of materials relating to the limit of their performance and technical limitations imposed by standards or customer demand. This kind of knowledge comprises 9.9% of the units of knowledge used for innovation. Personal knowledge is more important (52.3%), sources internal to the firm comprise 33%, and 14.8% of this knowledge stems from external sources, whereby suppliers, customers and consultants, but also scientific literature are relevant (Gibbons, Johnston, 1974).

The knowledge related to experimental R&D encompasses experimental and test procedures, research instrumentalities (the ability to utilise experimental techniques and equipment; the ability to interpret test and experimental results), research competence (general research competence; competence in a particular specialist area) and experimental and test data. Analysis and testing for any particular type of performance of a new product or process takes up 10% of all knowledge used in innovation processes. From among the sources of knowledge, personal knowledge is more important (50.6%), 19.1% comprise internal sources to the firm and 30.3% are obtained from external sources, especially hand- and textbooks, but also from suppliers and consultants.

The knowledge related to the final product comprises new product ideas, operating performance (performance of components or materials; pilot production, field trials and so on; user experience) and production competence (design requirements for manufacture; competence in pilot production/scale-up). New product ideas rarely emerge from a single step, but rather "coalesce" over a period of time (Faulkner et al. 1995). Production competence contributes to early concept design (ideally) as well as to the later detailed design through pilot production (Ibid.). Knowledge of operational performance comes from pilot production, direct trials and user experience. Knowledge of performance of materials and components comes from suppliers and users, and from experience (Ibid).

The knowledge related to knowledge encompasses the location of a particular knowledge, and the availability of equipment, materials, specialist facilities, or services. This category encompasses Gibbons and Johnson's categories of the existence or availability of equipment and materials with particular properties (respectively 13.9% of knowledge used in innovation), the existence of specialist facilities or services (3%) and the location of information (8.8%). The sources of sub-categories are slightly different, as the existence of equipment and facilities is mainly obtained from external sources; the location of information is mainly via personal knowledge. This category of knowledge involves searching and problem solving, and external contacts are widely used to locate facilities, literature and other contacts in particular specialist areas (Faulkner et al. 1995). From among the external sources for looking at existing materials and components, suppliers and customers are the priamary source, but in order to locate available equipment and information, universities are the main source (Gibbons, Johnston, 1974).

The broader categories of knowledge have relatively differing importance in different categories on the basis of the object of the knowledge. For example, skill-based and tacit knowledge is more relevant in design, R&D and production. Specific and local knowledge is significant in design, production and operating performance (Vincenti, Ch. 6, Faulkner, 1994:450).

As Vincenti (1990:199) argues, the tacit component in production will tend to decrease as automation increases, and descriptive knowledge must also enter, especially through the physical properties of the material. In design processes, detailed design will mostly be dependent on two types of explicit knowledge, but design at higher levels will need a great deal of tacit knowledge related to the feeling and judgement about the design. The easier and more inexpensive the access to knowledge the more it tends to decrease the economic value of codified knowledge and information and increase the value of knowledge that cannot be codified and transmitted electronically (tacit knowledge) (Wolf, Gertler, 2002:12).

Quantitative empirical evidence shows also that personal and internal knowledge sources[10] are of the most importance, ranging from the 51% to 66% from total knowledge used for innovation in different studies (see Appendix 4). In addition to that, the internal sources of the firm are most important for obtaining tacit knowledge (especially with regard to skills and artefacts). Still, tacit knowledge embodied in artefacts is obtained from other firms, but also from public sector research institutes who are also a source for skills and information in some industries (see Appendix 5). Formal knowledge is acquired from the public sector research institutes, but in the form of information also from other firms.

Although the internal sources in the firm (personal and internal categories) are evidently dominant, depending on the category, external sources can be highly relevant. For example, in searching for the existence of special kinds of materials, equipment or services, external sources are critical. It has to be noted that since competing firms as a source of knowledge has not been analysed in the studies (except for Vincenti (1991)), their role is therefore underestimated in this discussion. Research reveals that each type of knowledge was obtained predominantly from one particular general source (Gibbons, Johnston, 1974: 227).

1.2. Sources of knowledge for the innovative activities of a firm

1.2.1. Internal knowledge sources of a firm

By analysing the empirical assessment of the importance of different knowledge sources**,** the contribution of internal knowledge resources dominates. In different studies, internal knowledge sources carried 54–66% of the total knowledge used for innovation. To carry out a specific innovation project, from all internal knowledge, personal knowledge of the problem-solver accounts for slightly more than half (Gibbons, Johnston, 1974), the rest comes from other sources within the firm. At the level of firm, changes in the nature of work reflect changes in the distribution of knowledge within the firm and those shifts most frequently involve technology and technical experts as the central agents of

[10] From the studies, only Gibbons and Johnston (1974) distinguished between the personal knowledge of the problem solver and the internal knowledge of the firm; however, they found both to be of similar importance (from total knowledge, 36% personal and 30% internal sources were used).

change (Fleck, Tierney, 1991:6). Sometimes new technology can diffuse knowledge among wider individuals in the firm, but it can also concentrate specific knowledge in the hands of the workers using or maintaining this technology (Ibid.).

The importance of internal knowledge resources stems from the need to appropriate the technology embodied in certain artefacts (Pavitt 1984). As Faulkner et al. (1995:37–38) discuss, the ownership of intellectual property alone is not enough, one needs to have additional tacit knowledge and skills in order to make it work, and therefore the firms have to possess some in-house expertise in order to effectively exploit the technology. Even if the transfer of technology from external sources functions well, it cannot be a complete substitute for in-house knowledge searches; one needs to have a substantial in-house capacity for recognising, evaluating, negotiating and adapting the technology potentially available from other sources (Dosi, 1988:1132).

The ability of firms in a sector (that is empirically also assessed in terms of R&D) to take in outside knowledge and technology is denoted as *absorptive capacity* (Cohen, Levinthal, 1989, 1990). This capacity includes the basic skills of employees on the one hand, but also the broader knowledge of modern scientific and technological developments. This is relevant for the search activity firms pursue in order to identify new opportunities and resolve attendant problems (Faulkner et al. 1995:39). As Nelson (1982) notes, this knowledge is the capability of carrying out efficient searches and better orientation about where to search, and carrying out basic research activities can help.

The second reason for the importance of internal knowledge sources stems from the literature on the history of technology, showing the *cumulative nature of technology*. The development of technology in different fields seems to have path-dependency, and hence one speaks about technological trajectories and paradigms (Dosi 1988:1128–1130). Similarly, the acquisition and creation of knowledge at firm level is also cumulative – it is easier for firms to build new knowledge on an existing base than start afresh, and thereby the organisational learning and building up internal capabilities is very important (Faulkner et al. 1995:38). Vincenti finds that while knowledge for radical innovation may or may not come from outside engineering, most of the incremental innovations use the previously generated knowledge from the engineering field (1991:225).

The conclusion about the prevalence of internal knowledge sources in the innovation process can be drawn from the study by Vincenti (1991:194), where he finds that even after the communication of a specific design problem within an industry, each firm pursued their own innovation program due to a number of reasons: the necessity of obtaining hands-on experience (because all of the knowledge needed cannot be codified), but also the Not-Invented-Here (NIH) syndrome. The above-mentioned behaviour among firms resulted in the duplication of activities in different firms, but this was necessary because at first, the fundamental ideas of the respective design problem were known or obvious to single firms and the aptitudes and training needed for solving the problem were available throughout the industry (Ibid.).

The third reason for the importance of internal knowledge sources relates to *specific knowledge* as opposed to general knowledge. Pavitt's (1984) expla– nation of the specificity of knowledge stresses its necessity for product differentiation in the market and appropriability conditions. Dosi (1988) argues that low specificity in R&D allows firms to achieve synergy across product areas, but high firm specificity allows for a better appropriability. Specificity is related to the design and development work forming about ¾ of industrial R&D expenditure (Faulkner et al. 1995:38).

By studying the specific role of internal knowledge sources in the innovation processes of a firm, Gibbons and Johnston (1974) find (see also Appendices 6 and 7) that internal sources are especially relevant for design and test procedures and techniques, but also for knowledge about the properties of materials and components. In addition, internal sources are important for locating the information. It has to be noted, however, that all the aforementioned categories are heavily based on the personal knowledge of the problem-solver.

Faulkner et al. (1995) in their study show that internal sources are relevant for routine problem-solving, technical backup and experimentation and testing. Hence, Faulkner (1994: 438) concludes that knowledge obtained from internal sources is primarily related to the core activities of R&D and design. Therefore, the large-scale routinised corporative research activities have become one prevailing form of organising innovation activities, being most effective in exploiting technological knowledge (both, tacit and codified) (Pavitt, 1986). From internal sources as reported by Faulkner (1994: 438), the tacit skills acquired on the job were similarly considered as formal knowledge acquired from the literature and education. However, tacit knowledge is also acquired from other companies and from public sector research institutions. The internal industrial R&D activities also demand contributions from the external resources.

In contrast to the results of Rothwell (1977), Faulkner et al. (1995:179) find that new product ideas were derived primarily from a firm's internal sources often incorporating some stimulation or synthesis of inputs from other firms. As they conclude, new product development tends to 'coalesce' as a result of signals from different sources and therefore the sources of ideas are hard to trace; however, besides internal resources, the firms also have to follow what is happening outside.

There are different results from studies concerning the sectoral differences in the scope of the dominance of internal resources for innovation activities; for example, according to the development of new product ideas (these differences are discussed in a more detailed way in section 1.3.1).

One specific set of problems related to the internal knowledge sources of a firm is the case of firms belonging to a concern, especially as a subsidiary of a multinational corporation (MNC). Following the discussion above, the larger firms that incorporate more internal knowledge and experience encourage innovation. However, as Gupta and Govindarajan (1991) show, the knowledge flows between parent and subsidiary firms are different, according to the strategic contexts and innovative behaviour of subsidiaries, and are reflected in the formal and informal administrative mechanisms used by headquarters to influence decisions in the subsidiaries. Membership of the parent organisation or group gives an ownership specific advantage in terms of knowledge flows from subsidiary to parent (Veugelers, Cassiman, 2004) by having access to the parent's knowledge base, but also knowledge flows to the (global) external context through the parent's network. Although the MNCs knowledge base is generally believed to spill over into local economies, research by Veugelers and Cassiman (2004) shows that if controlled for access to international knowledge, the subsidiaries are less likely to transfer technology locally and be locally networked. Therefore, the advantage or disadvantage in terms of the subsidiary's internal knowledge sources for innovation is not uniformly determined.

In conclusion, the main reasons for the dominant role of internal knowledge sources in innovation processes are found to be the following (Faulkner 1994: 440):

1. To acquire external knowledge, some in-house expertise is needed (absorptive capacity argument of Cohen and Levinthal 1989, 1990; Dosi, 1988). Internal knowledge is needed for recognising, selecting, acquiring and using the knowledge located outside the firm.

2. The generation and acquisition of knowledge is cumulative at the level of the firm (path-dependency). This is especially relevant for tacit and skill-based knowledge derived from the internal capability and efforts of firms.

3. The role of specific (as opposed to general) knowledge in innovation (Pavitt (1984) and Dosi (1988) above). Internal knowledge sources are especially relevant for core R&D and design activities.

The questions not so clearly agreed upon in the literature relate to sectoral variation in the dominance of internal sources, the role of belonging to a concern and issues about which type of innovation activities the internal sources are most relevant for (product, process etc.).

1.2.2. Business partners as external knowledge sources

The Role of Users (Customers)

The role of users or customers as a source of innovation has been recognized since the 1970s (Rothwell, 1977; Kline, Rosenberg, 1986; Von Hippel, 1988; Lundvall, 1995). In the context of sectoral systems of innovation, demand is not viewed as consisting of similar buyers, but as consisting of *heterogeneous users* interacting in various ways with producers. Working with customers for innovation increases the likelihood that other customers will also accept this innovation. This kind of cooperation reduces the ignorance among manufacturers of customer needs, increasing user confidence in offerings and thereby reduces the risk associated with bringing innovations to market (Tether, 2002).

The most known in-depth study on the role of users in innovation is that of Eric von Hippel (1988). As discussed by Von Hippel, the users are often the *drivers of innovation* in both high-tech and non high-tech sectors. This is also a result of Vincenti revealing that the needs of users of a certain design impel the growth of a particular kind of knowledge in engineering (Vincenti 1991:12).

Von Hippel (1988: 14–15) by studying the innovations in scientific instruments finds that users (mostly researchers in universities) were the main innovators of such instruments, and the manufacturers commercialising the innovations admitted that their commercial product was based on a device developed earlier by the user (in terms of the same operating principle). This wouldn't happen if both users and manufacturers engaged in parallel independent research, but only rather through interaction. Shaw (1985) by analysing innovations in medical equipment found that in more than half of all cases they were user-developed initially and often those users helped the manufacturers to design, test and market the commercialised innovation.

In the case of process innovation for semiconductors and printed circuit board assembly, Von Hippel finds that users developed all the technique-only process innovations (meaning changes in the way in which the existing equipment is operated), which didn't require the implementation of any novel equipment and all multi-step process development concepts (1988: 23–24). Later, these process innovations filtered through to the manufacturers via interaction between staff members (which was difficult to avoid), but not always. Sometimes no transfer was seen, sometimes the transfer was made through purchase orders of units used for that detail, or an equipment user (not necessarily the innovator) adopted the role of equipment manufacturer. Hence, the role of users in process innovation besides typically considered product innovation also seems evident.

In the case of non-high-tech users having no formal R&D personnel (like pultrusion process machinery users in plastics engineering), the innovation occurred mostly when the user received a large order of uniform products, then a creative person on the factory floor "*used an innate sense of engineering design and machine parts lying around the factory*" (Von Hippel, 1988: 30) and sometimes it yielded innovation in terms of the process equipment that later filtered through to the manufacturers.

Andersen (1992: 83–84) differentiates between the production of mass products where interaction is not needed and *new products* where the interaction is crucial. Therefore, learning by using means processes involving trial and error, which require intensive informal contacts between partners. Tether (2002) finds that when products are novel and more complex (which might require adaptations in use on the part of the customers) or the market is poorly defined, collaboration with users is essential to ensure market expansion. Amara and Landry (2005) suggest that users are exploited more intensively as an information source by firms that initiate innovations as the world's first introductions rather than as incremental innovations. This concept is very much in line with von Hippel's "*lead users*" concept, where the lead users are characterized by (1) facing the general needs in the marketplace months or years before the bulk of the marketplace, and (2) benefiting significantly from obtaining the solution to that need (Von Hippel, 1988:107). According to this concept, a manufacturer looking for a product innovation should carefully examine the needs of a lead user.

The study of Gibbons and Johnston (1974) reveals that innovative firms receive knowledge from users about the existence or availability of equipment and materials with particular properties and the properties of materials and components (Appendix 8).

In general, vertical relationships between users and producers *reduce the costs* of communication and knowledge exchange, the *risks associated* with introducing new products and reducing the time needed for pushing the innovative product from the laboratory or design department to the market (Mytelka, 2002:92). Therefore, user innovation can be encouraged by shifting the expected rents from an innovation more towards the user (e.g. via appropriate design of the product, offering free equipment or design help for innovating users) (Von Hippel, 1988:99).

Industry level empirical analyses have shown that customer collaboration is positively associated with the use of customers and public institutions as knowledge sources, but also by firms with more intensive internal R&D activities (Belderbos et al. 2004). In contrast to other business sources, the size of the firm has been found to have less impact (Tether 2002, Belderbos et al 2004).

According to Shaw (1985) and Amara and Landry (2005), users influence product and process innovations in the following ways:

(1) by providing complementary knowledge and access to tacit knowledge, possibly also including the users technical know-how;
(2) by establishing a precise set of user requirements thereby helping to find the right balance between price and performance;
(3) by providing information about new or evolving needs;
(4) by giving information about user behaviour relevant for refinements to the innovation or post-launch improvements. The success of an innovation is dependent on the quality of knowledge about user needs (Faulkner 1994);
(5) by enhancing the likelihood that the innovation will be adopted by other firms within the same user community. This is particularly important when the user is well known and respected within the community and the manufacturer relatively unknown, but also in a situation where innovation is radical rather than incremental.

To summarise, users are drafted as a knowledge source for innovation due to their better market knowledge, which achieves the goal of reducing risk and cost and especially intensively by introducing novel and more complex innovations. If users are typically considered to contribute to product innovation, some case studies reveal that they are also important for process innovation, which needs to be verified at the industry level. The impact of the size of the firm has been found to be less relevant for absorbing knowledge from users than from other business sources.

Suppliers as External Knowledge Resources

Suppliers are used in a similar way to users to acquire innovation-related information (Teubal et al., 1991; Bruce et al., 1995). These relationships share many of the features of the relationships with the customers, because of the same vertical nature of the relationship (Tether, 2002). However, the information linkage is based more on either the making or buying decision of a manufacturer when it concerns the parts or details needed in the production process. The tendency in recent decades has been towards downsizing and focusing on core competencies, which is likely to increase the role of suppliers in innovation processes (Amara, Landry, 2005).

Suppliers and users are sources of foreign/global knowledge for a firm through exporting goods and services or importing materials and technology. The trading relationships form the nodes of international knowledge exchange as discussed widely in the literature on spillovers. At the macro level, the factors influencing *technology transfer* are related to the national infrastructure and the economic and social environment (Burgess et al. 1997). Sluggish technology transfer can also be viewed at the micro level from the perspective of technology users and producers (Lundvall, 1988; Gertler, 1993, 1995), where implementation difficulties arise because of insufficient interaction or ineffective communication between them. As Gertler (2002:115) points out, failures in achieving close interaction could be more severe in regions with a sparse endowment of technology producers. Von Corswant and Tunälv (2002) found the need for geographic proximity was also relevant. It seems that according to the more advanced manufacturing technologies (AMTs), successful implementation depends on collaborative buyer-supplier relationships (Burgess et al. 1997).

The close cooperation between the supplier and producer is not only relevant for adopting technology, but also for *producing new technologies*. The interactive mode of acquiring technology enables the user-firm to gather as much information about the technology as possible, thereby sensing the reliability of the supplier-firm. The supplier can similarly receive all the information concerning the specific client's needs; however, in order to reveal the close details of production processes to the supplier, both firms must have built up a sufficient trust level by interacting over extended periods of time.

Von Hippel (1988:35–40) lists examples of process machinery innovations that were made by suppliers of materials with the motivation of capturing rents from selling the materials. As shown by Sabel, Kern and Herrigel (1989), new supplier relationships in the automobile industry[11] have redefined industrial cooperation and advanced the development of the industry. Burgess et al. (1997) find that such relationships have created virtuous circle leading to more AMT implementation and more supplier collaboration contributing to business success. In addition to the technological processes, sharing information with suppliers is critical in coordinating work schedules to ensure that the sequence of tasks avoids unnecessary tasks or overlaps (Tannenbaum et al. 1992).

Although empirical studies show that while innovative efforts related to process improvements are more likely to involve cooperation with suppliers and product innovations with customers (e.g. Fritsch, Lucas, 2001), in addition to process innovations, the role of suppliers in *product development* has also been recognised. The suppliers can influence the speed (reduced time and R&D cost) and flexibility of product development processes, but can also offer access to new technologies and make it possible to improve the quality of products and new ideas for better products and features (von Corswant, Tunälv, 2002; Monzka, Morgan, 1995; Corsten, Felde, 2005). Hoegl and Wagner (2005) find that buyer-supplier collaboration helps regardless of the supplier's share of the project in terms of both the effectiveness (product cost and quality objectives) and efficiency (schedule and development cost objectives) of product development projects.

However, positive results are not always present; quite different results are presented by Littler et al. (1995), where cooperation made product development more costly and less efficient and manageable. Hence, there are additional factors involved that need further investigation. As Stank et al. (2001) also found, collaboration with external partners in the supply chain increases internal collaboration in turn improving the quality of services (logistics, for example).

The extent, to which the supplier can be incorporated into product development processes, depends on the supplier's capabilities, and the role that the manufacturer assigns to different suppliers. The success of involving suppliers in product development depends on several factors: the supplier should engage in cooperative activities with other manufacturers to have up to date knowledge (*supplier's capabilities*). Table 3 is compiled based on the study of Japanese automobile manufacturers and their suppliers; however, it can even be used as a raw model to discuss relationships in general in the manufacturing industry. As can be seen from Table 3, suppliers can be incorporated into the product development process to different extents at different stages of product develop-

[11] In fact, bulk of the research in supplier collaboration also presented in this section draws on Japanese automobile industry being as most eminent example of very successful tight cooperation.

ment; however, it seems that in design activities, the suppliers are relevant partners even if they are in the form of a child-type supplier. As reported by manufacturers in the study by von Corswant and Tunälv (2002:258), the competence of the supplier was often insufficient or too similar to the manufacturer, and did not contribute to the success of the project.

Table 3. Supplier roles in product development processes

Role Description, activity	Partner (Full Service Provider)	Mature (Full-System Supplier)	Child	Contractual
Description	Relationship between equals; supplier has technology, size and global reach.	Manufacturer has superior position; supplier takes major responsibility with close customer guidance.	Manufacturer calls the shots, and supplier responds to meet demands.	Supplier is used as an extension to manufacturers manufacturing capability.
Responsibilities during product development	Entire subsystem. Supplier acts as an arm of the manufacturer and participates from the preconception stage onward.	Complex assembly. Customer provides specifications, and then supplier develops system on its own. Supplier may suggest alternatives to manufacturer.	Simple assembly. Manufacturer specifies design requirements, and supplier executes them.	Commodity or standard part. Manufacturer gives detailed blueprints or orders from a catalogue, and supplier builds.
Design responsibility	Supplier	Supplier	Joint	Customer
Product complexity	Entire subsystem	Complex assembly	Simple assembly	Simple parts
Specifications provided	Concept	Critical specifications	Detailed specifications	Complete design
Supplier’s influence on specifications	Collaborate	Negotiate	Present capabilities	None
Stage of suppliers’ involvement	Pre-concept	Concept	Post-concept	Prototyping
Component-testing responsibility	Complete	Major	Moderate	Minor
Supplier’s technological capabilities	Autonomous	High	Medium	Low

Source: Kamath, Liker (1994:158, 164)

According to the cooperation activities, the suitability or match of the suppliers’ and manufacturer’s *organisational structure* as well as the role of the manufacturer as a coordinator of the project was also relevant for leaving the development responsibility to the supplier, which takes management and organisational skills (von Corswant, Tunälv 2002). Bessant (1991:339) finds that the key role in AMT implementation is played by organisational adaptation. The organisational structures are relevant for intensive socialisation leading to the emergence of trust, which is in turn relevant for exchanging tacit knowledge creating redundant and overlapping knowledge bases to increase the innovation potential (Nonaka, Takeuchi, 1995). Cooperation with the supplier is even more difficult when the cooperation involves second-tier suppliers and the knowledge from them has to be filtered through the first-tier supplier; in that case a formalisation of communication is needed (von Corswant, Tunälv 2002).

Strong buyer-supplier collaboration in the design and development of significant product components enable the partner to openly share the relevant information and holding back can lead to unnecessary changes and reworking later on (Hoegl, Wagner, 2005).

Kaufman et al. (2000) by studying the problem from the suppliers' point of view find that employee training and programs to develop supplier relationships are a relevant factor that encourages supplier collaboration. In addition, they find that if the firm develops either collaborative or technological skills, the relational rents are not gained; it has to develop both types of skills at the same time (Ibid, p. 660). Similarly, the importance of soft skills besides technical skills are stressed by Hoegl and Wagner (2005).

Von Corswant and Tunälv (2002:258) find that even if *global suppliers* were expected to have more potential for providing manufacturers with the necessary competence, the differences between them and smaller local suppliers were not revealed because the branch offices acted in many respects as local firms.

Empirical studies analysing cooperative innovation at industry-level have found that collaboration with suppliers was positively associated with the use of suppliers and public institutions as knowledge sources – supplier collaboration was used more by firms with higher R&D intensity, by larger firms and by firms with organisational and risk constraints, but less in firms with financial constraints (Belderbos et al. 2004). In addition, such manufacturer characteristics as consistent demand, profit levels, organisational structure, availability of specialists and relationship age are found to be relevant (Burgess et al. 1997; Corsten, Felde, 2005).

Gibbons and Johnston, by studying the specific knowledge gathered from suppliers, find that suppliers are the most important source of the existence and availability of equipment and materials with particular properties and design-based information, but also test procedures and techniques (Appendix 8). As Faulkner et al. (1995:205) found in their study, users and suppliers have wide informal linkages involving a lot of tacit knowledge related to the specifications or performance of materials or software incorporated in the final product. Gibbons and Johnston (1974) also find that suppliers provided or directly led to the solution of a problem being worked on or narrowed the location of the solution or demonstrated feasibility, but also evoked a basic idea not previously conceptualised in order to solve problem; however, more often than with other sources they contributed to an unsatisfactory solution (Appendix 9).

In conclusion, suppliers have been recognized as a source of innovation knowledge not only for developing processes, but also in developing new products and services and even design activities. Organisational risk and labour barriers influence knowledge exchange in a way similar to customers, but the financial constraints have been found to be less relevant. In some studies, exporting firms have been found to exert greater pressure for upgrading technologies and cooperating more with suppliers.

Competitors as External Knowledge Sources

A competitor as a source of innovation has been studied in the literature dealing with *strategic alliances*, but also in *cluster literature*. Horizontal collaboration between same sector SMEs yields *collective efficiencies* (Schmitz, 1989) – reducing transaction costs, accelerating innovation through more rapid problem-solving and greater market access (Mytelka, 2002:92). Openness of knowledge may speed up the pace of innovation as competitors are able to build on other innovators' advances rather than being allowed to block the progress of others (Foray, 1997). Agglomerations, much discussed in cluster literature, can cause positive externalities in the form of skilled labour, specialized suppliers and in some cases also positive technological externalities (knowledge spillovers) (Marshall, 1990; Krugman, 1991); Basant (2002) also adds a certain type of infrastructure. This type of cooperation, exploiting the dynamic capabilities of large and small firms, can be a relevant force encouraging innovation (Rothwell, 1989).

In earlier contributions to cluster literature, the division of labour, transaction costs and agglomeration effects were used in order to explain the process of clustering. The major focus was typically on input–output linkages or what has come to be called traded relations. More recent studies, however, have focused on dynamic efficiencies that emanate from learning at the cluster level. Storper (1995) has indicated that the focus should be shifted to untraded interdependencies, which include different methods of knowledge creation, sharing and utilisation. Storper stresses the idea that untraded interdependencies create observed input–output linkages, but are more enduring. Untraded interdependencies between enterprises in a cluster, apart from input–output linkages, contribute to knowledge flows and learning. This has caused a more rigorous exploration of cluster-specific innovative activities and the role of knowledge flows and their determinants in industrial clusters[12].

The above ideas of changing the relative importance of material and relational linkages inside clusters were linked to the life-cycle of clusters by Formica (2002)

[12] See the survey of the literature in Basant (2002: 5–12).

(see also Figure 3). According to his ideas, in the first phase of cluster development, companies collaborate by adjusting to existing technologies, and relationships are mainly based on tangible resources (raw materials, components etc.). In information exchange, personal relationships matter, collaboration is informal and tacit knowledge is transmitted. Experience from the coordination stage and existing supply chains leads the most innovative companies to invest in 'untraded' or non-commercial factors of interdependency, such as educational attainment, developing team work, communicating and promoting favourable attitudes towards industry (Storper, 1995). This means that joint rather than individual benefits are maximized. The later stage, 'co-opetition', is characterized by the same companies cooperating and competing with one another at the same time. As noted by Bengtsson and Kock (2000), the advantage of co-opetition is the combination of pressure to develop within new areas provided by competition and access to resources provided by cooperation.

There has been much criticism of cluster literature, from which more relevant empirical examples for this study show that clusters are very complex economic and cognitive spaces where firm's inter-cluster linkages (but also extra-cluster linkages) are not simply explained by their spatial proximity, but rather by their own particular knowledge bases (Giuliani, Bell, 2005).

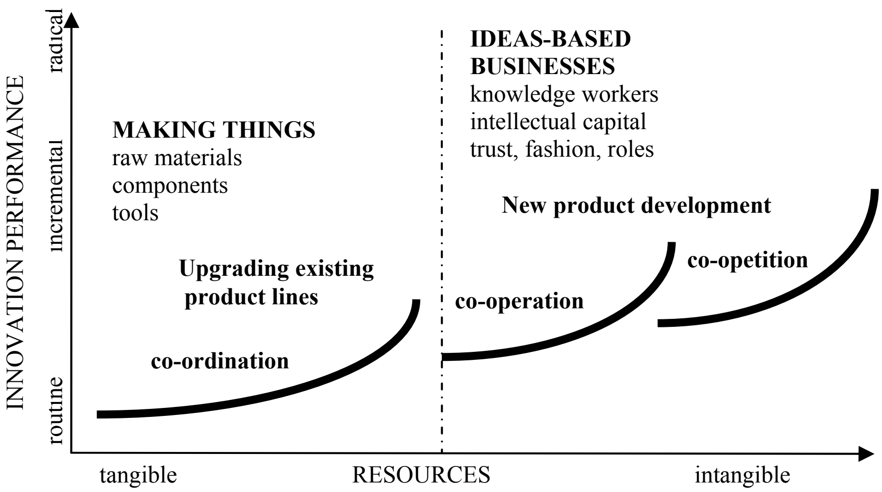

Figure 3. Forms of business collaboration in an evolving cluster (Formica, 2002:59)

The already existing cluster relationships can be transformed when one cluster member is aquired by an MNC. A study by Lorenzen and Mahnke (2002) revealed that often in such cases local networking is discouraged and inter-concern networking encouraged. The results of empirical studies of innovation cooperation also reveal that firms belonging to a foreign multinational use less competitor collaboration for innovation (Belderbos et al. 2004).

Caloghirou et al. (2004) argue that innovativeness is increased by partnerships in *alliances or strategic collaborations*. In addition to firms' interests in keeping certain knowledge secret to obtain a competitive advantage, there is also some interest in maintaining some collective knowledge that enables all of them to be innovative (Nelson, 1982). This knowledge can be shared in formal ways (patents, publications), but also by informal interactions. Faulkner and Senker (1993) found that some knowledge that is not sensitive commercially (like knowledge of instrumentalities) is extensively exchanged through informal interaction with the competitors' R&D workers and designers. Barden and Good (1989) found the importance of this interaction to be very influential in terms of the direction of activities, although it is not so frequent. Hagedoorn and Schakenraad (1990) have found that more than 85% of R&D joint ventures and various research cooperation activities are strategically motivated. Additional factors influencing cooperation between competitors are the size of firms (larger firms have more freedom to choose several types of cooperation activities), waves of technological development (radical changes encourage alliances), the maturity of the industry (in young industries strategic alliances are more relevant because of a high degree of uncertainty) (Vanhaverbeke et al. 2002).

In the discussion of the sources of innovation, Von Hippel (1988: 6, 76) finds widespread *exchange of technical know-how*[13] between competitors regardless of the fact that this is very often considered proprietary knowledge and is often protected[14]. This kind of knowledge exchange occurs because when the engineers do not have the knowledge within the firm (and developing such knowledge within the firm is expensive or time-consuming), they must find it outside. However, because it is highly specialized knowledge, they cannot find it in publications or elsewhere except through a firm that uses similar technologies. This kind of cooperation is present in cases where there is little competitive advantage (Von Hippel, 1988:77). Sometimes the workers of competitive firms are trained at no charge; personnel are sent to a competitor's factory to help set up unfamiliar equipment etc. (p. 79). In the case of direct rivals, firms try to avoid a direct exchange of knowledge (e.g. by not allowing plant tours etc.), but they concede that indirect exchange (through suppliers of machinery, customers etc.) cannot be avoided (p. 81–82). In contrast, Dahl and Pedersen (2004) found that competition clauses have been successful at limiting informal networking between their employees and those in other cluster firms. Never-

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[13] Defined by Von Hippel as the accumulated practical skill or expertise allowing things to be done smoothly and efficiently.

[14] Von Hippel focuses mostly on knowledge held in the minds of engineers working for a firm, enabling them to develop products and operate and develop technological processes (Von Hippel, 1998:76).

theless, the engineers, but also top management were aware of such know-how trading. This exchange must be reciprocal (therefore, Von Hippel calls it „know-how trading"). As noted by Schrader (1991), the rents the firm gains from shared know-how depend from the degree of competition.

As Faulkner et al. (1995:180) find, the researchers in firms keep up with the competitors' developments and highly value opportunities to exchange information and experience because there is a lot of 'shared methodology'. By analysing the typical know-how competitors are trading, Von Hippel (1988:86) identifies two characteristics typical to the units of knowledge traded between firms – it is not vital to the firm and it can be independently developed by any competent firm through an appropriate expenditure of time and money. In case such knowledge is traded, the net gain of the cooperation is larger than the net costs of developing the knowledge internally or to proceed without this knowledge (p. 87). As most traded know how offers no significant competitive advantage, some of it does (sometimes, temporarily) and in that case, know-how trading does not occur (p. 88). Sometimes, the trading offers competitive advantage or encourages collective competitiveness (e.g. by establishing uniform standards in a product category that can enlarge markets, or sharing knowledge on safety hazards) (Von Hippel, 1988:88).

Informal know-how trading can be seen as an inexpensive and flexible form of cross-licensing that functions best under appropriate conditions while having lower transaction costs and risks (Von Hippel 1988:89). If the knowledge (or willingness to share it) does not exist in the network and the individual firms do not find it reasonable to develop independently, collective R&D is preferred (Von Hippel, 1988: 90). As found via the empirical study of cluster literature, technical knowledge of new products, but also of standard equipment is shared through informal contacts, but general knowledge is even more frequently shared. This kind of knowledge has been recognised as having medium value in the work of an engineer (Dahl, Pedersen, 2004). In firms in low-tech industries, where product and process innovation are incremental, the firms especially tend to learn from the successes and failures of their competitors and by that experience improve their own strategy, technology and organisation (Antonelli, Calderini, 1999; Maskell, 2001).

There are several authors that stress the role of trust and inter-personal relationships as being a relevant factor for sustaining collaborative relationships (Lawton-Smith et al. 1991), whereby frequent and informal information exchange reveals the existence or establishing of mutual trust (Gelsing, 1992:119). Know-how trading partners, in the study by Dahl and Pedersen, (2004) were found to be former colleagues, classmates, but also private friends, in addition the longer work experience in the industry was one facilitating factor of informal knowledge exchange and increased the probability of acquiring useful information from informal know-how trading.

As with any other cooperative activity, cooperation with competitors requires management skills including lateral communication, openness and conflict resolution (Larsson et al. 1998).

Faulkner et al. (1995:205–206) find that some formal knowledge between competing firms is exchanged via publications or patents, but recognise that informal knowledge sharing might be even more important. Their experience shows that the technical staff in firms quite frequently communicate, and opportunities are quite often created by government or industry meetings to establish standards (this is also proposed by Tether, 2002). In this way, they focus on areas of common concern without disclosing proprietary information. They conclude that several types of tacit knowledge are transferred between competitors in this way. Therefore, *industry associations* are forming a more formalised avenue for competitor collaboration.

Industry-level empirical studies show that collaboration between competitors is positively associated with the use of competitors and public institutions as knowledge sources and firms with risk barriers to innovation (Belderbos et al. 2004).

To summarise know-how trading, according to von Hippel (1988:98) informal knowledge trading is most effective if the know-how needed: (1) belongs to some member of the network, (2) is proprietary only by virtue of its secrecy or (3) has small unit (module) value compared to that which requires an explicit contract or licence (otherwise, licensing would be preferable).

Amara and Landry (2005) have concluded on the basis of existing business management literature that information obtained from competitors relates to the increased complexity and intersectoral nature of new technologies, the reduction of uncertainty and R&D costs associated with market access or the development of product and process innovations (by the acquisition and appropriation of the partner's tacit knowledge or uptake of codified knowledge; by the reduction of the period between invention and market introduction). The methods include collective R&D contracts, licensing and informal know-how trading. Tether (2002) highlights three areas of collaboration with competitors in search of innovation: (1) related to standard setting, (2) in learning more about the competencies of rivals and (3) when they face common problems (e.g. in the regulatory environment).

In conclusion, competitors are similarly used to enhance innovation with other business partners – for risk and cost calculations. However, collaboration with competitors is different because it is more informal (although it can also be formalised via R&D contracts or collaboration activities via industry associations). It is not clear however, which part of the knowledge is exchanged – technological, design or market knowledge, or all of the aforementioned. Exchanging knowledge with competitors is usually hindered when firms belong to a lerger concern or group.

Consultants as external knowledge sources

Consultants can represent a rich source of valuable, albeit short-term capabilities (Nevo et al. 2007). When the internal resources are not sufficient, contracting research out or employing consultants can be cheaper for firms than hiring somebody permanently. This helps in assisting with specific problem-solving or with movement into unfamiliar technologies (Faulkner et al. 1995: 22). As Giuliani and Bell (2005) show via the example of a Chilean wine cluster, consultants may be an important source of frontier (international) knowledge and techniques. Even in low-tech SMEs (food industry cases) the share of firms using consultants for the development of products or processes was found to be relatively high (consultants were used in the field of legal work and accountancy) (Avermaete et al. 2004). Bruce and Morris (1998) suggest that even though internal designers are thoroughly familiar with the firm's products and approach, they often become content and stop proposing innovative ideas – these fresh ideas may be obtained from external design consultants. Bessant and Rush (1995) find that consultants provide experience, share ideas between firms and encourage collaborations with other firms.

As Nevo et al. (2007) found by studying IT firms, when a firm's own capabilities were low, the use of consultants increased their productivity, but when there existed a higher level internal knowledge, the firms would be better off not hiring consultants or relying on external expertise.

The study by Gibbons and Johnston (1974) reveals that consultants were used to provide various test procedures and techniques and also knowledge about operating principles or rules, the required specifications and/or technical limitations (Appendix 8). For a specific innovation project, consultants narrowed the area of the potential solution or demonstrated its feasibility, but also provided or directly led the way to a solution for the problem being worked on (Appendix 9).

In conclusion, consultants are used as a more formal and costly way of innovating when the firms own knowledge resources are not sufficient. They are used for several activities (product, process and design innovation etc), and the relative importance of these activities probably depends more on the innovative activities currently relevant for that specific industry.

If one takes all the commercial networking partners together, then they are most important for providing research equipment, but also in assisting with production activities and determining future innovations (Appendix 10, Faulkner et al. 1995). As shown by Dodgson (1993), linkages with external partners (competitors, suppliers, users) increased dramatically in the 1980s, both in number, but also in terms of the format of the cooperation. This seems to be because of new technologies, which from one side make collaboration easier or stimulate collaboration, and from the other side they are the object of collaboration (Mytelka, 1991; Freeman, 1990).

1.2.3. Universities and R&D institutes as external knowledge sources

Increasing competition, shorter product development cycles and rapid development in technologies have generally promoted the idea that universities, in addition to their basic research function, have an additional function to fulfil – to provide applicable knowledge in collaboration with firms that can lead to commercial innovations. Besides the reasons mentioned above, the firms might locate their RD&D activities abroad as the major source of knowledge as part of the globalisation process – increasing interaction with universities is also found in research-intensive industries where the close proximity and interface of different disciplines is relevant and finally, the respective efforts of governments enhance this kind of interaction (Faulkner et al. 1995:13–14). Mansfield (1998) finds that over 15% of new products and 11% of new processes would have been delayed or could not be developed at all without academic research involved, and 8% of products and 7% of processes were developed with substantial assistance from recent academic research.

There is a growing body of literature specifically studying the role of universities and public research organisations in innovation. This literature encompasses the approaches to innovation, but there are also specific (empirical) studies concerned with the organisations under discussion. According to Martin et al. (1996), universities and research institutes are helping to disseminate and apply knowledge in the following interrelated and overlapping ways: by increasing the stock of useful knowledge, by training skilled graduates, by creating new scientific instrumentation and methodologies; by forming networks and stimulating social interaction; by increasing the capacity for scientific and technological problem-solving; and by creating new firms.

There are also benefits for the universities and research organisations: additional research funds[15], students and staff coming into contact with practical problems, jobs for graduates and access to specific technological areas (Gibbons, 2003; Vermeulen, 2003). However, there are also obstacles in this kind of cooperation that stem from the different orientations. Fowler (1984) studied the barriers to cooperation and found that they relate to different orientations and cultures in universities and firms (the sort-term orientation of industry on profits, the mismatch between orientation towards basic research in universities and the need for applied research by firms, a lack of understanding stemming from these different cultures). In addition there was a very different attitude

[15] In fact, this factor can be more relevant as commonly considered. As Mason et al. (2004) find by studying UK and French research systems, the severe financial constraints of UK universities have induces many academic departments to take highly pro-active approach for looking at the new potential sources of income by the industrial partners.

towards publishing vs. protecting the research results. Senker (1990) studied cooperation with universities in biotechnology and found that there is great deal of suspicion and antagonism in such relationships. As Faulkner et al. (1995:22) conclude that the main limits to such collaboration with universities are found in three factors, from which the last one is the most important in any formal cooperation:

1. The flows from academia yielding commercialisable products or technologies are limited;
2. There are institutional limits originating from the deep-seated differences in orientation and culture;
3. It is economically beneficial for firms to conduct most of their RD&D internally.

The *channels of interactive learning* between the public sector research infrastructure and private companies can be very different in terms of how formalised the interaction, the transfer of tacit knowledge and the personal contacts are (see also Schartinger et al., 2002 for more details). However, as found in the study by Faulkner et al. (1995:188), even if firms acknowledge the gains from education and literature, the most important knowledge received from public sector research was tacit knowledge and skills in both, individual contacts and collective R&D projects with universities. The relative importance of information, knowledge, skills and artefacts varies between sectors as knowledge and skills being high in biotech and technical information and artefacts important in ceramics (ibid).

Training skilled graduates and producing knowledge applicable to the industry are different strategic directions for universities; however, they are connected in encouraging the innovative activities of firms. Generally, the exploitation of any external source of information (including universities) depends on the average absorptive capacity of a firm (Cohen, Levinthal, 1990). This capacity includes the basic skills of employees from one side, but also a broader knowledge of modern scientific and technological developments. Since technological learning entails a great deal of learning by doing (producing) and learning by using (the technology or materials), not only do the absorptive capacity become relevant, but also technology adaptation and improvement, especially for technology followers. As discussed by Helpman, Rangel (1999) and Caselli (1999), skilled workers bear lower costs in the use of new technologies than unskilled and the adoption of new technology is hence easier, which is important for incremental innovations in technology-followers. Therefore, in the case of low-tech firms, training activities in specific technology areas may fit the needs of individual firms better (Freel, 2004; Taylor, 2001).

There is a significant role in the technological processes described above to play off *technological gatekeepers* within the firm (Klobas, McGill, 1995). The role of such gatekeepers is often crucial for technological development in sectors that do not have a high share of technically skilled workers, since the gatekeepers are able to obtain the necessary knowledge from outside the firm through networks. As already found by Gibbons and Johnston (1974), a problem-solver's university education in the innovation process in a firm encourages the use of the university as a knowledge source. In fact, the share of university graduates working in the respective industry represent long-term relations in the field of human capital, but also the certain proximity of scientific and industrial knowledge. This is found to be the second most important factor besides R&D intensity that explains interactive learning with universities (Schartinger at al., 2002: 320). The study by Mason et al. (2004) reveals that industry-academia collaboration is encouraged by the higher professional mobility of high-quality (PhD holding) engineers and scientists, especially by creating new relationships with universities that can be particularly advantageous to a fast changing high-tech industry (for example, the electronics industry).

However, this relationship (especially for SMEs) can be *non-linear* – firms with a moderate strength of internal knowledge have a higher probability of interaction with the public research infrastructure than those with weak and strong knowledge sources. Firms with limited internal capabilities do not recognise the opportunities to collaborate with external partners. If knowledge sharing with external partners increases, there exists a greater probability for diminishing returns on knowledge. Similarly, the firm with a greater internal knowledge base reassesses its own endowment in relation to the potential of complementary external knowledge sources, and may find that the latter decrea–ses while slack resources can be found within the firm (Meeus et al. 2004: 333).

Another issue, which has been raised by Cohen and Levinthal, is that the ease of learning from outside sources also depends on the degree to which outside *knowledge is targeted* to the specific concerns and needs of the firm. When outside knowledge is less targeted to the firm's needs, then internal R&D becomes more relevant for recognising the value of the knowledge, to assimilate and exploit it (Cohen and Levinthal, 1990:140). The universities and public R&D institutes typically produce information that is less targeted. Faulkner et al. (1995:23–24) discuss that the strength of the linkage depends on the extent to which industry considers the knowledge generated by public sector research institutions relevant to the current needs. The empirical results of Cohen and Levinthal (1990: 145–147) show that the effect of the increased use of knowledge sources from basic science (e.g. universities) elicits more R&D compared to that of applied science (e.g. government labs).

In the literature, external and internal knowledge sources are often seen as complementing innovation; however, firms may seek external knowledge in order to substitute for expensive or risky R&D efforts. As noted by Vavakova (1995), cooperation with universities or research centres may ensure a critical amount of R&D for those projects that are considered too risky or expensive for a company. So the firms compensate their R&D via partnerships with public research institutions. This is especially relevant for SMEs in low-tech industries often lacking the internal resources for R&D activities (Baardseth et al. 1999). In particular, when coupled with the availability of public funding opportunities, universities and R&D institutes are seen as an inexpensive form of specialised knowledge (Belderbos et al. 2004). Additionally, the universities are becoming more applied; the role of academia is changing the concept of Triple Helix (Etzkowitz and Leydesdorff, 2000).

As brought out by Howells (2002), the ability to scan different knowledge and information sources is strongly related to the size of the company. This has also been supported by the empirical evidence in the case of universities – larger firms and firms with stronger R&D intensity use universities as an innovation source relatively more often (Sakakibara, 2002; Laursen and Salter, 2003); however, there is evidence of contrary results (Santoro, Chakarbarti, 2002). Dahl and Pedersen (2004) have found that the management and production engineers tend to have higher levels of knowledge acquisition from competitors than R&D engineers (and this might come from their relatively longer work experience, but also from the extra chances to visit conferences and other events).

Traditionally, the weaker appropriability of the gains from internal R&D has been seen to discourage internal R&D, but as shown by Cohen and Levinthal (1989), the spillovers have also a positive, absorption-capacity-building effect. As found by Veugelers (1997), external sources may also stimulate internal R&D expenditure. Link and Rees (1990) have found that firms that collaborate with universities gain more than two and a half times higher returns on their R&D expenses than other firms (a result obtained in a cross-sectional study of 209 firms). Berman (1990) presents that collaboration between firms and universities speeds up industrial research activities in universities and hastens knowledge transfer from academia to industry. Cassiman and Veugelers (2006) find that reliance on universities and research centres as innovation sources is an important contextual factor that influences the extent to which combining internal and external knowledge increases a company's knowledge development potential (Cassiman, Veugelers, 2006: 69).

In addition to that, firms can benefit from the reputation of working with a prominent academic institution (Frombrun 1996). Faulkner et al. (1995:24) claim that firms seek local and overseas academic partners with a strong international reputation, because relating this to their strong research capability and institutional arrangements are suitable for industry liaisons.

From additional factors, Faems et al. (2004) have found a positive association between cooperation activities with universities and sales of products new to the market, but other cooperation types were related to sales of products new to the firm. Belderbos et al. (2004) find that public sector R&D cooperation is used by larger and more R&D intensive firms and firms with organisational and financial barriers.

By analysing sectoral similarities and differences in interactions with public sector research institutions, Faulkner et al. (1995: 177–178) show that as the intensity of formal linkage varies, informal linkage activity is widespread across sectors and informal linkage is both, a precursor and a successor of formal linkage (Ibid., p. 181). In all sectors they analysed, internal sources had more importance compared to external, but the relevance of public sector research institutions stood in a different position as being more or less relevant compared to other firms as knowledge sources.

As the formal linkages were so diverse, informal linkage in all sectors was based on active networking, trust building (considered important) and bartering (considered very common). The importance of literature vs. contacts (chance meetings mostly at conferences are valuable) and also less importantly, recruitment as sources of obtaining information from universities, was different in different sectors. The importance of literature emerged in biotechnology where much of the new knowledge has been codified in recent years, however in some other fields (e.g. parallel computing) the literature has been seen as being too abstract and has little practical value (Faulkner et al. 1995:182–183). In addition, the use of literature and contacts with public sector research representatives was found to be a function of personality, education and work experience (Faulkner et al. 1995:183). The literature and contacts are distinct knowledge inputs, but they are often used in combination, since the literature is often outdated, it is a first source of information and the researchers are often contacted later for further and more detailed information (Faulkner et al. 1995: 183). Therefore, the literature cannot be a substitute for contacts (Faulkner et al. 1995:191).

The common benefits obtained from linkage, according to Faulkner et al (1995), were similar across sectors in terms of keeping up with the research frontier, general and specific assistance with problem-solving, access to expertise in strategic and peripheral areas and goodwill. But different benefits across sectors were associated with assistance in experimentation, keeping in touch with public sector research and receiving feedback on products and marketing. All sectors gained a certain amount of knowledge from the linkage, but some also gained certain skills, artefacts and technical information. All sectors scanned the research frontier and underpinning knowledge, but some had an impact on instrumentalities and future innovations. As Faulkner et al (1995:190) conclude, the firms mainly receive two types of knowledge from linkages with the universities:

1) new knowledge in specialist fields of engineering and science,
2) practical help for problem solving, instrumentalities.

Strategic research in firms always had some involvement from public sector research in firms, but in some firms (especially SMEs), strategic research couldn't be done without some public funding, in others, public funding encouraged research in some peripheral areas (Faulkner et al 1995:185–186).

Factors influencing collaboration between firms and public sector research institutes are summarized by the following taxonomy proposed by Faulkner et al. (1995:192–197).

(1) Industry/sectoral factors – the character of new product development – whether it is knowledge-led or more interactive involving user-supplier feedback (the linkage is stronger in the first case). The size of the firms along with R&D intensity increases the intensity of interaction, whereby the size effects tend to overlay sectoral differences (Faulkner et al. 1995: 193). Small firms faced considerable resource constraints to both, formal and informal linkages (Faulkner, 1994: 193, Corsten, 1987) and communication problems (Rothwell 1973). No influence from the size of R&D teams (Faulkner et al. 1995:193).

(2) Public sector research related factors – the availability of expertise in public sector research is a crucial factor in industry-public sector research linkage (Faulkner et al. 1995:193). The examples from Faulkner et al. (1995) and Peters, Groenewegen, Fiebelkorn (1993, unpublished, quoted in Faulkner et al. 1995) show that the low level of the use of public sector research institutes as knowledge sources does not imply a lack of research interest in industry in respective research frontiers, but rather the paucity of available public knowledge and modern equipment vital for development. Therefore, there is less scope for contributions from public sector research in innovation in the respective business field (Faulkner et al. 1995:193). Moreover, the availability of specific expertise is relevant for firms despite the general research activities (Faulkner et al 1995: 193).

The public policy context is relevant especially for small firms overcoming resource barriers for cooperating with public sector research institutions (Faulkner et al. 1995:194). The role of the public sector as a key user was found to be relevant in many areas (in parallel computing by Faulkner et al. (1995:194–195) and other fields; however not in the wood-related sectors, however this can become relevant for developing new energy solutions;

(3) Technology-related factors – in process-related technologies where the role of industrial users is more relevant, the use of public sector research is less relevant than in product-related technologies, and the relative importance of tacit knowledge and the extent to which knowledge in the respective field is codified plays a role in contacts vs. literature (Faulkner et al. 1995: 195). The intensity of formal and informal contacts can change over the development stage of the industry or technology. For example, Faulkner et al. (1995: 195–196) find, that the relative age of a field influences linkage with public sector research (meaning that in emerging fields the intensity of interactions is higher – as the technology becomes more established, the intensity declines). In

addition, dynamism – the rate at which the new knowledge are emerging in the field.

(4) Firm-level factors – where the existing knowledge base is not sufficient (especially in fields new to the firm), linkage is more relevant. In terms of the propensity for linkage, Faulkner et al (1995:197) discuss that some firms are more „extrovert" than others and the reasons are hard to identify. They found that recruitment policy is relevant because of the networks new employees can bring to the firm (e.g. employees with doctoral or post-doctoral experience usually have networks within academia, but also know literature sources). The other factors they suggest are the proprietary concerns of the firm, but also the openness of senior RD&D staff, which from one side reflects the organisational culture, but from the other side also influences it. If firms in the traditional sectors are mostly not considered to have a close knowledge exchange with a public sector R&D base, then Meeus et al. (2004, p.345), and also Schartinger et al. (2002, p. 315) find the contrary – the industries under discussion revealed higher intensities of interactive learning with universities.

1.3. Integrating the types and sources of knowledge used in innovation

1.3.1. Synthesis of the types and sources of knowledge used for innovation in the context of the wood sector

Industrial firms gain ideas for innovation from different sources, and since knowledge is idiosyncratic at firm level and does not diffuse automatically and freely, their innovative performance depends on how successful they are at appropriating knowledge from these sources (Von Hippel, 1988; Cohen, Levinthal, 1990). Both internal capabilities and openness towards knowledge sharing are important for developing innovative performance (Caloghirou et al., 2004).

As revealed in sections 1.1 and 1.2, each knowledge category is related to a specific source, where it is in most cases obtained. The personal knowledge of the problem solver and internal sources of the firm are critical in almost all categories of knowledge, except for the information about the existence and availability of materials and components and specialist facilities and services. Not surprisingly, the scientific and engineering theory used in innovative activities is obtained from the universities or scientific literature. There is a consensus in the literature that the knowledge related to design practice and experimental R&D is mainly sourced from different business partners (suppliers, customers, competitors, consultants) and also from public sector research associations and literature, but the relative importance of different sources has not been determined and is obviously dependent on the type of innovative activities, firm characteristics, sectoral specifics, partner characteristics and institutions.

In Table 4, the categories of sources and the type of knowledge in terms of the object of the knowledge relates to the activities within the innovation processes of firms. By analysing the role of different sources of knowledge in the innovation processes, the following summarising results can be seen. Table 4 reveals that the future innovations are mainly conceptualised internally, but that the search activities is concentrated more on external sources, whereby the public sector research base (literature as well as public sector research institutions) plays a more important role. In routine problem-solving R&D activities, firms rely mostly on internal knowledge resources, but in this various literature sources are used. Other firms are used less, but have contributed to some unsatisfactory solutions. Concerning the research instrumentalities, the equipment is mainly obtained from business firms, but testing facilities from universities. Of course, the relevant skills are mainly internal to the firm. In addition, most production and technical back-up activities are obtained from internal knowledge sources.

Table 4. Innovative Activities and Sources of Knowledge

Innovative Activities	Main Sources of Knowledge (% from the respective knowledge used for a specific type of activity)		
	Internal	Other firms	Public sector
Future innovations (F)	57%	33% (*77%*)	10 %(*33%*)
Search activity			
Scouting for new applications (F)	45%	27% (*49%*)	28% (*51%)*
Scanning research frontier (F)	30%	18% (*26%*)	52% (*74%*)
Evoking basic idea to solve problem not previously conceptualised (GJ)	n.a.	33.3% (Suppliers)	66.7% (Technical literature)
Ongoing R&D			
Underpinning knowledge (F)	40%	2% (*3%*)	58% (*97%)*
Routine problem-solving (F)	88%	9% (*75%*)	3% (*25%*)
Defined basic parameters of problem (GJ)	n.a.	25% (Customers)	75% (Handbooks, research associations)
Stimulated action leading to the solution of the problem (GJ)	n.a.	10.4%	89.6% (All kinds of literature, both types of institutions)
Provided or directly led to solution of the problem being worked on (GJ)	n.a.	31.3% (Suppliers, consultants)	68.7% (Trade and scientific literature)

Innovative Activities	Main Sources of Knowledge (% from the respective knowledge used for a specific type of activity)		
	Internal	Other firms	Public sector
Narrowed area of solution of demonstrated feasibility (GJ)	n.a.	30.2% (Suppliers)	69.8% (Trade and scientific literature)
Contributed to unsatisfactory solution	n.a.	83.3% (Suppliers, customers)	16.7% (Scientific literature)
Instrumentalities			
Research equipment (F)	18%	52% (*80%*)	30% (*20%*)
RD&D procedures (F)	47%	24% (*46%*)	29% (*54%*)
Skills in experimentation and testing (F)	55%	17% (*37%*)	28% (*63%*)
Enabled testing the idea to be carried out (GJ)	n.a.	28.9% (Suppliers)	71.1% (Universities)
Production (F)	51%	46% (*93%*)	3% (*7%*)
Technical back-up (F)	73%	10% (*36%*)	18% (*64%*)

Note: The % in italic show the respective share from external sources
Source: Author's compilation of the results of Faulkner et al. (F) (1995) and Gibbons and Johnston (GJ) (1974)

This table reveals the general patterns of knowledge use in firms. The literature on sectoral systems of innovation discusses the differences in the use of knowledge among firms along with the main actors in the system and institutions influencing the system. The question of differences in innovation processes in general across economic sectors[16] has interested many scholars and initiated several studies (see Peneder (2003) for a review of different studies and classifications). In this section, only some of most influential among them are considered.

The first and most common is the taxonomy of the OECD dividing the industries by R&D intensity (calculated by the relative importance of R&D expenditures and dividing sectors into high-tech, high-medium-tech, low-medium-tech and low-tech). This taxonomy, although commonly used, has received a lot of criticism for ignoring and over simplifying different patterns of innovative activities in different technological fields.

The first division of industries/technologies stems from Schumpeter – two general patterns of innovative activities labelled as Mark I and Mark II were identified. The Mark I category refers to a strategy, where new innovators constantly enter the market and the competitiveness of existing firms is eroded,

[16] According to Malerba (2004:9–10), a sector can be defined as a set of activities unified by a related group of products or emerging demand and share some basic knowledge. However, firms in the sector can share similarities in the technology base, but can also be heterogenous in many respects (size, product portfolio, strategies etc).

this can be called the 'widening' strategy[17]. Mark II refers to existing dominant firms innovating using the accumulated knowledge base and can also be called a 'deepening' strategy. The empirical analysis of Malerba and Orsenigo (1996) shows that the wood sector belongs to the Schumpeter Mark I category according to its low concentration of innovation activities, low stability, high birth rate and low firm size.

One can also divide sectors by whether they are (net) technology suppliers or (net) users. For example, the analysis by Scherer (1982) that studied 400 firms in the US and the analysis by Robson, Townsend and Pavitt (1988) based on a UK sample, have found that the core technology supplier industries are the computer industry, electronics machinery, apparatus and chemical industry, who create most technologies for the users who are textile, metallurgy, car industry, services etc. Wood-related sectors can be included in the latter category as users of machinery and equipment produced by other industries.

The fourth taxonomy by Pavitt (1984) distinguishes four groups of industries according to the sources of technologies and knowledge and profit appropriability mechanisms:

1. Supplier-dominated industries (textiles, services), where new technologies are obtained from the suppliers by investing in new components, or equipment and technology transfer occurs mainly through learning by doing and learning by using (hence internal knowledge sources dominate). Appropriablility is weak.
2. Scale-intensive sectors (car and steel industry), where process innovation is crucial and both internal knowledge sources (R&D activities, learning by doing) and external sources (suppliers) are used. The appropriation mechanisms are used in the form of patents and trade secrets.
3. Specialised suppliers (equipment producers), where innovation processes concentrate on improving results, reliability and consumer friendliness. The knowledge sources used are internal (experience-based, skilled technicians within the firms), but also external (user influences), and the appropriablity stems mainly from the local and concentrated knowledge, but also from interactions;
4. Science-based sectors (like pharmaceuticals, electronics etc), where product and process innovations are rapid, the knowledge used is internal (R&D activities), but also external stemming from universities and research institutes and the appropriability mechanisms vary from patents and waiting times to different learning curves and trade secrets.

Pavitt's taxonomy has been successful in the sense that it has been confirmed in many empirical surveys for analysing sectoral aspects of innovative activities. This taxonomy has also been elaborated (e.g. Marsili, Verspagen (2002)).

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[17] This strategy encompasses the behaviour known as 'creative destruction'.

According to Pavitt's taxonomy (1984), wood, furniture and paper industries belong to supplier-dominated sectors by the characteristics of their technological development and innovation. This means that the dominant external sources of technology and information are suppliers, government-financed research institutions and less frequently large users. In these industries, competitor collaboration may often be present. Oerlemans et al. (1998) find that in supplier-dominated industries, important innovation partners include large suppliers and buyers, but also other companies in the same industry. They additionally find public technology policy to be an important contributing factor to innovation in these sectors. If the traditional sectors (or supplier-dominated sectors (Leiponen, 2001)) are mostly not considered to have a close knowledge exchange with the public sector R&D base, then Meeus et al. (2004, p.345), but also Schartinger et al. (2002, p. 315) find the contrary – the wood industries revealed above average intensities of interactive learning with universities. It has to be noted that Pavitt's taxonomy is based on the database covering firms in the UK over an extended period. If we consider that the wood sector is not as large, important and well developed in the UK economy as in some other countries (e.g. Nordic countries and Austria, but also Estonia), then the results from Schartinger et al. might also reflect the much stronger R&D specialisation in a country (Austria) where these sectors have been more important traditionally.

In wood-related sectors, constant incremental improvements rather than radical changes in technological processes have occurred recently. The analysis of case-studies in Palmberg (2002) reveals a very close interrelationship between product and process innovation in these industries (similar findings for food sector firms have been found by Avermaete et al. 2004). Palmberg finds the incremental innovations related to sawing, gluing and jointing techniques in the glue-lam timber industry adding additional new characteristics to the end product. The same for pulp and paper industry technologies is shown by Laestadius (2000). These incremental changes in the processes have used the late achievements from different high-tech sectors.

Traditionally, according to OECD taxonomy, advances in the technological development of different sectors in the economy are assessed through R&D intensities that are relatively low in the industries under discussion. The markets where wood sector firms operate are very competitive ones, where the appropriability conditions for technology and innovation are weak because in many cases the products are relatively easy to imitate, at least at first sight (Palmberg, 2002:25). The depleted technological opportunities and saturated markets to a certain extent explain the low R&D levels in these sectors. Most of the research is done for those industries by other sectors; for instance, by equipment manufacturers, and chemical or biotechnology firms. Those firms are often highly specialised, concentrated and operate world-wide (e.g. harvester and forwarder producers or paper mill equipment producers), so it makes the latest technology available everywhere (ILO 2001:50). State-of-the-art technology is diffused to developing and transition countries via FDI, but not necessarily – there are examples of larger firms in developing countries that do well without the help of that kind of foreign capital.

The concept of absorptive capacity described in section 2.1 includes from one side the basic skills among employees, but also the knowledge of modern scientific and technological developments. Since technological learning entails a great deal of learning by doing and learning by using, there is a kind of technological capability relevant especially to firms in low-tech industries. This is the capability to introduce new combinations of existing technologies and is sometimes known as '*architectural capabilities'* (see Henderson, Clark (1990)). Such capabilities are not reflected in the industry's R&D-intensities or educational indicators. However, these capabilities contribute to innovation (especially process innovation) and technological change.

Competitive markets force the companies in those sectors to be very creative regarding the capabilities of running and readjusting their machinery and equipment. As discussed by Laestadius (1995) and Hircsh-Kreisner et al. (2003), this demands different types of knowledge from firms compared to R&D-based technological change and innovation. This type of knowledge is tacit and captures practical engineering problem-solving by engineers and technicians, but also shop-floor workers. Laestadius (1995) argues that this kind of knowledge in the firm also supports the innovation stemming from external sources to the firm (through collaboration with universities, R&D-institutions or suppliers of machinery and equipment). The importance of these above-mentioned driving sources of innovation in wood-related sectors can also be found in Pavitt's taxonomy (1984).

As mentioned above, the wood sector uses the technologies, but also other processes which are the result of innovative activities in other sectors (equipment producers, chemicals etc.). As discussed in section 2.3, the adoption of new technology is hence easier for skilled workers. However, increases in the demand for skilled workers during the adoption process will disappear as the implementation of technology is completed (Chum, 2003). There is a significant role that the technological processes described above play as technological gatekeepers[18] within the firm (Klobas, McGill, 1995). They may be appointed individuals with formal dissemination responsibilities, influential persons in the firm or "gatekeepers", who are recognised as experts to whom others turn to for reliable information. Those are the key persons within the firm with the personal ability to translate and communicate relevant external scientific or technological knowledge throughout the firm. In the literature, these gatekeepers are quite well

[18] This term was first used by Allen (1970). Typically, this is a person to whom the employees turn if they or their colleagues cannot find a solution to the problem and who then points to the source of knowledge where they might possibly find a solution.

vested; they have a supervisory role vis-à-vis product and process development, as well as a long employment history with extensive contacts within the firm (Palmberg, 2002: 30). The role of such gatekeepers is crucial for the technological development of wood sectors, where there is not a lot of technically skilled workers. Faulkner et al. (1995:183) have also found in every firm one or more such gatekeepers with strong internal and external linkages. In wood industries, the most important role of gatekeepers could hence be seen in adapting the new technology and facilitating process and product innovation through networks of suppliers, customers, but also research institutions.

In the study of specific types of knowledge for innovation activities by Faulkner et al. (1995), some interesting sectoral differences are revealed, but unfortunately, the industries analysed are not similar to wood industries – probably the closest to the wood sector being the engineering ceramics industry (see also the figures in Appendixes 5, 11 and 12). They find evidence that the types and sources of knowledge transferred via linkages with business and public sector partners are quite different. The results summarized in Appendix 5 reveal that internal sources are important for tacit skills and knowledge about artefacts, where technological tacit knowledge is especially relevant in production and research activities in the engineering ceramics industry (and this makes it similar to the wood sector). In the case of engineering ceramics, technical information (formal knowledge) besides tacit knowledge came more intensively from business partners. Formal knowledge from universities (acquired through education and reading the literature) was important for all sectors, but again tacit knowledge obtained from the public sector plays a relatively more important role in the engineering ceramics industry. As Faulkner et al. (1995:188) conclude, the types of knowledge of particular importance in the ceramics industry include knowledge about technical information and production inputs obtained from both business and public sector research sources, and again this makes this industry relatively similar to the wood industry.

By considering the stages in the innovation processes (see also Appendix 11), Faulkner et al (1995) find that by identifying new product areas, the engineering ceramics industry differs from other industries in the sense that through articulating user needs and receiving feedback on existing products, other business partners become the main source of knowledge along with internal sources (Figures 1,2, and 3 in Appendix 11). The other interesting difference is that the public sector research base is exploited more to obtain knowledge for new R&D procedures, research equipment and skills in experimenting and testing (biotechnology and parallel computing, for example rely more on internal sources or other firms) (see Figures 7–9 in Appendix 11). In other activities, the industries behave relatively similarly (scouting for new applications and underpinning knowledge, public sector research is used, for routine problem-solving, knowledge for new process technologies and production methods, internal technical back-up sources are more relevant (see Figures 4–6, 10–12 in Appendix 11). The relative importance of internal vs. external business vs. public sector knowledge sources is assessed differently, but for engineering ceramics one can see (Table 1 in Appendix 11) that all sources are relatively more equally important for innovation – parallel computing relies more on internal, and biotechnology, on public sector research sources. By accessing public sector knowledge sources, literature and contacts play a relatively more important role, and therefore, knowledge about instrumentalities is especially relevant for the engineering ceramics industry (see also Appendix 12).

To summarise the above-described research, one can see that the specific characteristics of the wood-related sectors are mainly revealed in close relationship to product and process innovation, and the importance of the architectural capabilities of firms and the relevance of technological gatekeepers within the firm. Therefore, the internal (in the form of personal knowledge in the case of gatekeepers, but also in regard to shop-floor workers) sources are relevant. However, as tacit knowledge is more relevant for the type of technologies this sector uses, this is obtained in great part also from external in addition to internal sources. In terms of external sources, suppliers, but also customers and competitors are relevant. The importance of public R&D institutions and universities is in terms of the technological, R&D and testing skills and equipment, but this also seems to be associated more with a public R&D specialisation.

1.3.2. The substitutability and complementarity of knowledge sources

Although most innovative activities and knowledge categories have one dominant source, there are additional alternative knowledge sources that possess similar knowledge that can be used as a substitute for the main source of specific knowledge needed in the innovation process. Therefore, quite different opinions can also be found in the literature about the substitutability of different sources of knowledge, especially when the broader theories described in subsection 1.1 are considered. Microeconomic theory in general does not deal with separating categories and sources, and so it is not important whether the knowledge is acquired from outside or created internally. The transaction cost approach could lead to the idea that internal sources are preferable because of the transaction costs with other parties, but also the NIH syndrome when using external sources. The resource-based strand argues that when the firm's internal knowledge resources are not sufficient for innovation, external complementary resources are sought to help with innovation, whereby existing linkages are intensified and new linkages created (Aiken, Hage, 1968: 930; Combs, Ketchen

1999: 868). These somewhat contradictory viewpoints can be analysed via the very simplistic model described in Figure 4.

According to Dosi (1988), economic agents allocate resources to obtain knowledge for innovation if they expect some economic net benefit from such innovative products or processes. As brought out by Von Hippel (1988:44–47), some additional preconditions have to be met. First, the innovating firms cannot easily shift their functional roles (because this is costly). Second, they benefit from the innovation themselves rather than by licensing them to others (because, again, of the associated costs and risks). In addition, the expectations from innovation-related rents must differ significantly between firms in different functional relationships to a given innovation opportunity.

There are some specific assumptions made when modelling the choices of such firms:

(1) *The decision-maker* – the decision-maker is a firm, and the internal decisions within the firm are left aside, meaning that all possible negotiations among the employees in the firm are not accounted for. This simplifying assumption can ignore several aspects related to different possible decision rules in the group and the way group characteristics and other factors influence the decision making processes within the firm – these are discussed by the literature on organisational behaviour[19]. Because of the disaggregate nature, this model has to account for the characteristics of the decision-maker, but there is no automatic process for performing this identification and therefore, the actual application and available data justify this kind of choice (Bierlaire, 1997:3–4). Therefore, in this model, the decision maker is a manager or the management, whose utility function is highly relevant for making decisions about building internal knowledge resources or using external ones under uncertain conditions. As Fleck and Tierney express, we cannot be sure "…*whether management have the appropriate knowledge to even start understanding what these new bundles of knowledge and skills might be, especially in times of highly uncertain and turbulent technological change, or in situations where innovation is an issue.*" (Fleck, Tierney, 1991:6). It has to be noted that in SMEs, which describes most Estonian wood sector firms, very often the owner and manager coincide[20].

(2) The alternatives – possible options (choices between alternative knowledge sources) for decision makers. According to Bierlaire (1997:4), all the options that the firm has (potential choice set) need to be described, including the alternatives that were not chosen. However, this is difficult in reality. Firms search for knowledge in fields that build on their existing knowledge bases

[19] See for instance, Coyle-Shapiro, Kessler, 2002; Clark et al. 2000.

[20] It is not possible to analyse who answered the Community Innovation Survey questionnaires (probably some members of management), but from the interviews conducted most respondents were owners and managers at the same time (58%), managers (37%) and management (several respondents of management) (5%).

(technology, markets, distribution channels etc.) (Teece, 1986). The choice of an alternative strongly depends on the nature of the technological/design problem the management seeks to solve, but in the case of innovations, the firm can face a lack of knowledge of these alternatives and their costs and possible outcomes (Freeman, 1982, Nelson 1981, Nelson and Winter 1982). In addition, not all knowledge sources are available for all firms (e.g. concern sources are certainly more open to member firms). Therefore, the sources available in the CIS questionnaire are again used for an empirical analysis of the model.

(3) The decision rules – the description of the process that a firm uses in order to make its choice of the knowledge needed for its innovative activities. In the case of R&D, the firm has a set of decision rules that is usually called a "search strategy" in the innovation literature (see e.g. Nelson, Winter, 1982: 249). Ben-Akiva and Lerman (1985) summarize the different rules from the literature down to four categories: dominance (an alternative is dominant over another if it is better for at least one attribute and no worse for all other attributes), satisfaction (an alternative is preferred if it meets some satisfaction criterion for at least one attribute and is no worse for all other attributes), lexicographic rules (the attributes are ranked by their "importance" to the decision-maker and the alternative is chosen that is most attractive in terms of the most important attribute) and utility (ordinal and cardinal utility) (Ben-Akiva, Lerman, 1985: 35–38). However, considering the specific problems of this research are "*better described as a selection of one of a finite set of discrete bundles of attributes*" (Ben-Akiva, Lerman, 1985:58), and therefore discrete choice theory (in particular, probabilistic choice theory) seems more appropriate. From the different interpretations of the probabilistic choice theory, the random utility approach is used, where utilities are treated as random (because of observational deficiencies stemming from the unobserved attributes, tastes, measurement errors and use of proxy variables) and it is assumed that the decision-makers will always choose an alternative with utility that exceeds the utility of the other alternatives (Ben-Akiva, Lerman, 1985:58).

(4) The attributes – these assumptions identify the attributes of possible alternatives that a firm takes into account when making their choice. Considering the choice to use and acquire the innovation related knowledge, the search strategy may depend on different attributes of the firm itself, such as size, profitability, actions of competitors, payoff from R&D, evaluations of the ease and difficulty of obtaining certain technological advances and in particular, the complex of skills and experience the firm possesses (Nelson, Winter, 1982: 249). However, as shown in the previous sub-sections of this chapter, the content of the knowledge needed for the specific part of the innovation chain that is relevant for a firm in its current activities, the various characteristics of the internal and external innovation environment and capabilities of partners (in case alternative external knowledge sources exist) can also be regarded as attributes.

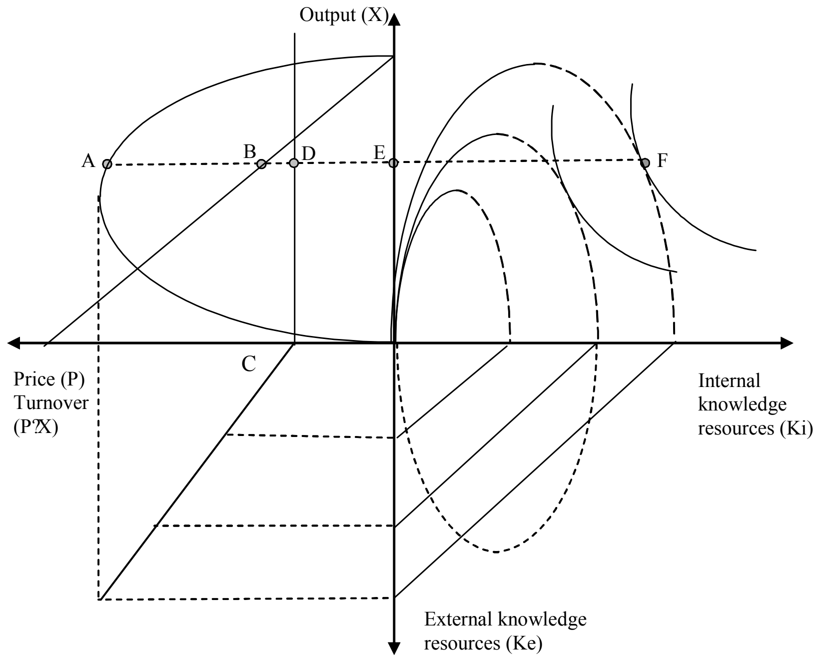

Figure 4. The Choice of Internal and External Knowledge Sources[21]

The discussion about the choice of internal and external knowledge sources of a firm is summarized by a simple model shown on Figure 4.

I Quadrant. On the axes of the Figure 4 the turnover and cost curves and innovation-related (expected) profit or rent from innovation in between them is shown. Higher profit in production can result in higher price of products (but rather through increased sales), cheaper production costs or from better equipment compared to competitors meaning the higher sales through better quality of the product.

The determination of the expected profit is not easy, because it is not based on some straightforward calculation, but rather depends from the unpredictable actions of competitors, emergence of other innovations etc.[22] (Von Hippel, 1988:58).

[21] This kind of model has been originally developed by Nam, Kaltschuetz, Friedrich (2004) for describing the behavior of public firms, but here appropriately amended.

[22] The firm wants to lower its innovation costs by shifting some of the project development costs to material suppliers or demanding some in advance payments from buyers. The firm also tries to increase the share of the benefits the innovation yields, e.g. by charging higher price to capture some e.g. fuel saving benefit the innovation gives to the user of this product. Buyers and suppliers, at the same time attempt to pursue their profit maximising strategies. (Von Hippel, 1988: 58)

It is widely discussed in the literature, that innovators are capturing the rents by first establishing a temporary monopoly control over the innovation to increase their return. As contradiction to common understanding, by Von Hippel (1988, Ch. 4) finds that the licensing (patenting) and trade secrecy typically is not allowing to achieve this kind of rents (which is very much true for low tech firms). Therefore, the innovators must get profits from excluding imitators through response time, which exists because of many barriers in addition to the lacking knowledge (engineering tooling, ordering materials and components, etc) (Von Hippel, 1998:59). It is also shown that when imitators enter, the fist-seller reputation matters. Of course, this response time depends from the situation: in case there is an expensive capital-equipment involved, which buying decision process is long and imitation shorter, then the monopoly rents cannot be collected (Von Hippel, 1988:73–74).

The innovative activities differ according to the rent expectations of a potential innovator because of abilities of firms to protect and benefit from the identical innovation related information the innovator possesses because of the functional role they have to the innovation opportunity (Von Hippel, 1988:72). Of course, the innovation activities depend also form the wider competitive structure of industries involved (the same innovation opportunity could involve firms with different functional roles from various industries having different structures etc.). Since the rent from the innovation is not only depending from the innovating firm, these kinds of factors are relevant (Von Hippel, 1988:72).

II Quadrant. Here the utility function of management is presented depending from the profit, output and internal knowledge resources. The contribution of internal knowledge resources is here (similarly to labour in all similar micro-models) having decreasing marginal product (marked with dotted line) because similarly that in case of labour, there might be dichotomy of the specialisation and the degradation of the repetitive tasks – "*Individuals and groups may well decrease the scope of knowledge and competences that they are required to put into production or innovative search (in a sense they may be required to "forget"), while at the same time these same individuals and groups become linked to through routines that increase organizational efficiency (or whatever criterion the latter is evaluated)*." (Dosi, 1988:1133)[23]. As automation increases, tacit component of some detailed knowledge categories in production will tend to decrease Vincenti (1990:199), because the e.g. skills of making the machines and skills of using them, become increasingly separated (Dosi, 1988: 1133). This requires larger organizational capabilities of storing and using more complex knowledge. Furthermore, the boundaries of firms can be defined by the core competences representing the relevance of specific knowledge to the

[23] There is the alternative discussion of knowledge having increasing returns usually in macro-models of the economic growth (like Romer's growth model), but also in some micro-models (see Antonelli's recent discussion, 2006).

activities associated with a certain product determining the efficient vertical integration and specialization of any firm (Dosi, 1988: 1133). This discussion is also in line with Von Hippel's condition of the high costs for switching the functional roles.

III Quadrant represents the trade-off between internal and external knowledge sources. This can be represented through different options depending whether the sources are treated as complementary or as substituting each other. As can be concluded from the theoretical discussion, there are opposite positions about the complementarities or substitutability of firm's internal knowledge and the knowledge stemming from external sources. In addition, different external sources have been also found to complement each other. For example, in engineering design process many difficult trade-offs may be required that demand decisions under incomplete or uncertain knowledge and in case the knowledge is not available, special internal, but also external research may have to be undertaken (Vincenti 1990). Generally, the firms fund the use or external sources (such as public sector research) in cases where they do not have in-house expertise (Faulkner et al. 1995:184). In the case of new products, in the process of problem-solving, the "*eventual solution of a problem often coalesces as a result of inputs from both external and internal sources*" (Faulkner et al. 1995:186). The complementarity of internal and external knowledge sources is analysed in more detail below.

IV Quadrant represents the available financial resources for acquiring external sources of knowledge given the costs to internal knowledge and a self-sufficiency condition.

It is commonly agreed that the interactive learning with other actors in the knowledge infrastructure permits the firms to overcome the resource-based constraints for innovative activities (Meeus et al. 2004:332). These kinds of activities become especially relevant in times of moving to new areas where the firms' internal knowledge is restricted (Metcalfe, Gibbons, 1988). Not only is the existence of networks relevant for learning as it sometimes seems from the discussions in the literature. Networking has to be the mean for realising a common path of development through learning. The content and shape of a network as well as the degree of external network differs by product and production processes (Storper, 2002:150).

According to Maillat (1991), external resources are of little use for firms with incremental innovations, because the resources needed for these innovations can usually be found inside the firm. Firms with radical product and process innovations would require more than their limited internal resources can provide (Tether (2002) finds, R&D cooperation is more intensive by the firms pursuing radical innovations). Oerlemans et al. (1998) find that firms with incremental innovations use both types of sources – internal as well as external. The reason is that the gradual development of technology makes it easier to join internal and external resources, since the gap is smaller. In addition, as brought by Howells (2002), the ability to scan different knowledge and information sources is strongly related to the size of the company.

The choice between internal and external knowledge sources is also analysed by Metcalfe and Gibbons (1989). They argue that firms must articulate for producing a given set of artefacts, and they articulate knowledge most effectively in fields familiar to them (because of path dependency and cumulativeness of knowledge). It is difficult to them to extend their knowledge base to new areas, but external knowledge is especially important in case of radical innovations. As Faulkner et al. (1995:190) remind the external linkage is no substitute for internal capability. Hence, innovation is rather a synthesis of both, internal and external knowledge inputs (Pavitt, 1984). For example, the study of wine industry has shown that the higher level of internal knowledge sources (measured in terms of absorptive capacity), the higher also external openness of the firm (measured by the number of linkages with external knowledge sources) (Giuliani, Bell, 2005). They divide the firms by the strength of internal knowledge resources to four categories: sources, absorbers, mutual exchangers and isolates and show that all of these categories are related to the cognitive distance between firms and centrality of the firms in the network – the more capable firms, the more likely the firm is to improve the quality of the products by the virtue of such linkages.

By recognizing the processes of downsizing and focusing on core competences in large firms, Tether (2002) finds, that innovation cooperation with supplier tend to complement internal R&D efforts rather that substitute them. Most of the literature argues for the complemenarity of internal and external knowledge sources, however there is literature finding interesting evidence that in some cases like in the case of low-tech SMEs (see Baardseth et al. 1999 study described earlier in this section), the public sector R&D can be substitute for internal R&D activities assuring a critical amount of R&D for those projects that are considered too risky or expensive, in such way firms compensate their R&D via partnerships with public research institutions (Vavakova, 1995).

Individual sources of external knowledge can be also complementing (or substituting) each other, for instance Belderbos et al. (2004) find the cooperation with a type of business partner is chosen if the partner is recognised as relevant source of knowledge while the universities and R&D institutions are used complementary and having positive impacts to all types of cooperation. Arora and Gambardella (1990: 374) find by studying large biotechnology firms that innovation related agreements with other firms and research agreements with universities are correlated even after controlling for firm characteristics.

Generally, the vertical value-chain interaction is supposed to complement the use of other external knowledge source; however, as Hoegl and Wagner (2005) point out, buyer and supplier project members in communication overloaded situations may be less likely to search for additional information or technical alternatives, which could be valuable to the innovative projects. Von

Corswant, Tunälv (2002) find, that in case the suppliers used technical consultants, who were not familiar with the manufacturer's organisation, the knowledge transfer was limited.

The universities and public R&D institutions can be seen as substitutes to some extent offering similar knowledge. As Mason et al. (2004) find by analysing the differences in French and British research systems, the French firms tended not to be engaged with the university collaboration having at the same time close involvement with public laboratories, while the British firms were more engaged with university contracts.

It has to be noted, that the analysis of complementarity and substitutability of various knowledge sources is still underdeveloped in the literature and there can be no patterns of sectoral specificity discussed. From the existing literature, the conclusion of the complementarity of internal and external, but also most of the external sources seems to be plausible.

2. SOURCES OF KNOWLEDGE USED IN INNOVATION OF ESTONIAN WOOD SECTOR FIRMS

2.1. Innovation activities in Estonian wood sector firms

2.1.1. Data and methods

In this study, empirical data from several different sources collected using different methods are used:

1. Two consecutive surveys – "Innovation in Estonian Enterprises 1998–2000" and "Innovation in Estonian Enterprises 2002–2004" are used[24]. These surveys are generally based on the same methodology of the "Community Innovation Survey (CIS)" version 3 and version 4, respectively, developed by the European Commission and Eurostat and were conducted by the Statistical Office of Estonia[25];
2. General economic indicators for the industry collected by the Statistical Office of Estonia in its Electronic Database;
3. Nineteen interviews of industry managers conducted by author between June and September 2006. In addition, and in order to describe an earlier period, interview transcripts with wood industry managers were used from 2003 (these interviews were conducted by Prof. Urmas Varblane and Senior Researchers Tõnu Roolaht and Tiia Vissak).

The selection of different data sources was motivated by the research question. The Community Innovation Survey methodology was designed to measure technological innovation (Pavitt, 2005), which makes it suitable for analysing innovation in most wood sector manufacturing firms. In addition, the survey has questions concerning how intensely different knowledge sources for innovation have been used. However, this survey has shortcomings too – several authors have pointed out the failure of CIS methodology in describing design related innovations relevant in the furniture industry, for example. Additionally, the CIS surveys do not include the forest industry, which is closely related to the wood, paper and furniture industries. The CIS data covers the following industries in the wood sector:

- wood processing and production of wood-related products (NACE 21), involving sawmilling and planing, the production of veneer and wood-based

[24] The reviews of the surveys are given in Kurik et al. 2002 and Terk et al. 2007.
[25] Hereafter, the respective Estonian surveys are called shortly also CIS 3 and CIS 4 to avoid using the longer names of the surveys.

panels and boards, but also the production of other wooden products ranging from commodities, windows and doors to wooden houses;
- the furniture industry (36.1);
- the pulp- and paper industry (22), involving the production of cellulose, paper and board and related products (such as packaging products etc).

In addition to the CIS data, the surveys with industry managers were conducted to obtain more detailed information about innovation processes, future developments and possible obstacles for leading firms. The interviews were not aimed at studying the knowledge sources specifically, but were rather meant to provide a more thorough background to analyse the results of the empirical analysis of the CIS data. The survey was part of the project about Estonian Regional Innovation Strategy (ERIS)[26] aimed at studying the regional innovation linkages in industry clusters, but the questions concerning cooperation activities were useful for this study as well. To satisfy these aims the questionnaire covers a wide variety of topics (see Appendix 13).

The CIS3 and CIS4 samples

The CIS3 and CIS4 samples comprise about 41–57% of all firms in the population (see Table 4.1.1). In the first sample, paper firms have much greater representation compared to the other sub-sectors, representing even 86% of employment in the pulp and paper sector. In the second survey, the significance of the sample firms in the population is more balanced across sub-sectors.

From the 335 wood sector firms covered by the first survey (1989–2000), only those enterprises which have realised a product or process innovation in the period 1998–2000 are included. So the sample consists of 112 firms belonging to the wood industry (6 to paper, 66 to wood and wood processing, and 40 to the furniture industry).

The second survey (2002–2004) covered 216 wood sector firms, from which 139 innovative firms were included in the sample (including 14 paper, 69 wood processing and 56 furniture firms).

The econometric methods used in the data analysis are described according to each empirical section so as to be connected better with the interpretation of the results.

[26] The homepage of the project is http://www.eesti-ris.info/content/view/1/1/

Table 5. The coverage of CIS surveys by number of employees

Sub-sector	Population (2002)		CIS (1998–2000)			Population (2005)		CIS (2002–2004)		
	N	%	N	% from the sample	% from the population	N	%	N	% from the sample	% from the population
Wood Processing	19775	47	8878	51	45	18660	57	9322	50	50
Pulp and Paper	1457	3	1257	7	86	1832	6	863	5	47
Furniture	12551	30	7421	42	59	12264	37	8418	45	67
Total	42451	100	17556	100	41	32756	100	18603	100	57

Sources: Statistical Office of Estonia, Electronic Database; Innovation in… 1998–2000; Innovation in… 2002–2004.

Description of the interviews and interview samples
By compiling the preliminary sample, 30 of the largest and most influential wood sector firms were selected by presuming that those would drive the main innovation linkages in the sector. In this process, the representativeness by sub-sector and region was also accounted for. To identify the potentially relevant firms for the sample, the regional top lists of firms on the basis of sales turnover, profits and exports have been used[27]. The final sample covered 3–44% of total sales in different sub-sectors (see also Table 6).

Table 6. The coverage of the 2006 interview sample according to sales

Indicator	Forestry	Wood processing	Pulp and paper	Furniture	Total
Total sales (Mill EEK, 2005)	4908.019	14426.695	1629.530	4066.398	25030.642
Sales in sample companies (Mill EEK, 2004/2005)	2149.028	1574.967	41.847	620.288	4386.130
Share in sales (%)	44	11	3	15	18

* based on short-term statistics
Sources: Author's calculation based on the Electronic Database of the Statistical Office of Estonia (www.stat.ee), interviews, annual financial reports and ÄP Net (http://net.aripaev.ee/index.html)

The interview data represent about 4–13% of the population measured according to the number of employees (see Table 7). In the sample of interviews in 2003, paper firms have a higher representation compared to the sample from 2006, but here the problem was that there was only one paper firm in the sample and on the basis of numbers of employees this firm accounts for about a third of the industry. Since the interviews for 2006 have been targeted towards larger firms, the representativeness is higher. Again, in forestry the State Forest Management Centre was included in the sample, employing about a third of all forestry workers. The pulp and paper industry is under-represented according to the interviews, involving only one packaging firm.

[27] The top lists are compiled by the newspaper Äripäev; however, the disadvantage of this information source is in the voluntary inclusion of firms in the list and one regionally important firm was identified that did not belong to the list because of the respective strategy of the owners.

Table 7. The coverage of interview data sources according to the number of employees

Sub-sector	Population (2002)		Interview data (2003)			Population (2005)		Interview data (2006)		
	N	%	N	% from the sample	% from the population	N	%	N	% from the sample	% from the population
Forestry	Not included					3791	12	1433	33	38
Wood Processing	19775	47	514	29	3	16961	52	1791	42	11
Pulp and Paper	1457	3	528	29	36	1743	5	89	2	5
Furniture	12551	30	760	42	6	9905	31	970	23	10
Total	42451	100	1802	100	4	32400	100	4283	100	13

Sources: Statistical Office of Estonia, Electronic Database; Innovation in… 1998–2000; Interviews 2003: Agasild, Arula, Botvinkina, Kull, Kukk, Kolk, Kuldkepp, Karjus.

As can be seen from Tables 6 and 7, the largest sub-sectors covered in the sample are as follows:

- forestry (NACE 02), encompassing silviculture as a statistical category (including tree nurserys), but also the forest industry (wood procurement), additionally other service fields, such as monitoring etc;
- wood processing and producing wood-related products (NACE 021);
- furniture industry (36.1);
- pulp- and paper industry (22).

In addition to the above-listed larger sub-sectors, some firms that belong statistically to other industries (e.g. the production of musical instruments (36.3) and wood trading (51)) were included[28].

In addition to the representantiveness on the basis of sub-sectors, coverage of all regions has been attempted; however, this condition was not fulfilled, because major producers of different sub-sectors are not dispersed evenly in all regions and the importance of the wood sector is not similar in the respective regional economies.

Table 8. Distribution of the sample according to the size and ownership

Number of employees	Domestic Ownership	Foreign Ownership	Total
1–20	1	0	1
21–50	3	0	3
51–100	4	0	4
101–250	3	3 (Finland-2, Germany-1)	6
251–	3	2 (Denmark-1, Swizerland-1)	5

It must be noted here that several of the firms interviewed were the mother-companies of domestic or international concerns, and in such cases, the interview covered the innovative activities of the whole concern, and that has extended the share of sub-sectors covered by the interviews even further.

Most of the firms in the sample were established at the beginning of 1990s. However, since the wood sector has very long traditions in Estonia, the history of several enterprises reach back to the beginning of the 20th century and the oldest firm in the sample considers the history of its predecessor from 1734. It is interesting to note that this company operates even today in the same historic buildings. The youngest two firms in the sample were established in 2000. As can be seen from Table 4.1.4, the sample is biased towards large companies; micro-companies have been left out. The smallest firm in the sample employs

[28] In the calculations they are shown under wood processing sub-sector.

19 employees, while the largest, 1182. Most of the firms in the sample belong to domestic capital; foreign ownership is present in 5 companies. From the type of ownership, one firm in the sample is based on state revenue, which is the only one of its kind in Estonia; however, this is typical considering the same field in other countries in Northern and Western Europe.

The complete list of interviewed managers and firms is presented in Appendix 14. The interviews lasted an average of 1 hour and 19 minutes (the shortest 53 minutes and the longest 2 hours and 25 minutes). Most of the interviews were conducted in Estonian, only one was in English. The interviews were recorded[29] and transcribed later and were sent for verification to each of the interviewees. As the transcription was precise, it confused several managers who didn't want to make public many of the details they had given during the interview, therefore the results of the interviews are codified to avoid recognition and are quoted in the brackets [] with the respective codes.

2.1.2. Innovation activities in the Estonian wood sector 1990–2006

General development of the sector

Estonia occupies fourth position in Europe in terms of per capita provision of forest resources after Russia, Finland and Sweden[30]. Therefore, forest-related sectors have played a significant role in the Estonian economy, comprising 3.1 – 5.8% of GDP over the past ten years[31]. In recent years, the share of GDP has decreased, revealing that in light of rapid increases in GDP, forest related sectors have grown more slowly. These sectors employ about 7–8% of the total number of employees; however, in recent years, the decrease in employment was largest in forestry and mainly related to structural reforms in state forestry management (Teder et al., 2007). The largest sub-sector is the wood processing industry, comprising 55.4% of the total turnover of all forest related sectors, the next is the furniture industry with 19.5%, forestry and forest industry (18.9%), and the smallest is the pulp and paper industry (1.63%). Outputs have constantly grown in all of the sub-sectors in recent years and, for example, in per capita production of wood-based panels, Estonia has achieved third position in Europe and fourth position in the per capita production of sawnwood[32].

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[29] In two interviews, the method was different. One interview was not recorded, but written down at sight (because the interviewee didn't agree to be recorded) and one other interview was fulfilled electronically by the management team and sent to the author.

[30] Calculations are based on the FAO electronic database FAOSTAT for the year 2004 [http://faostat.fao.org/faostat/]

[31] Calculations are based on the electronic database of the Statistical Office of Estonia [http://www.stat.ee/]

[32] Calculations are based on the FAO electronic database FAOSTAT for 2004 [http://faostat.fao.org/faostat/]

Table 9. Main economic indicators for Estonian firms in 2000–2006

	2000	2001	2002	2003	2004	2005*	2006 I q.*
All firms							
Sales (Mill EEK)	254,649	291,411	327,727	354,411	417,176	452,748	118,000
Exports (Mill EEK)	55,999	67,022	74,449	81,190	104,095	–	–
Profits (Mill EEK)	12,581	13,515	18,483	22,749	29,074	49,873	9,7
Number of firms	30787	32690	34511	36895	39623	34472	37787
Average number of employees	380572	385575	402240	406694	417314	414419	426990
Wood sector firms							
Sales (Mill EEK)	16,346	19,195	22,280	23,366	25,881	26,031	7,549
Exports (Mill EEK)	7,563	8,762	11,142	12,003	13,057	–	–
Profits (Mill EEK)	0,744	1,092	1,486	1,336	1,392	2,019	0,634
Number of firms	1605	1703	1804	1946	2054	1733	1960
Average number of employees	30828	33864	36044	36787	36408	32029	33931
Share of wood sector firms							
Sales (%)	6,42	6,59	6,80	6,59	6,20	5,75	6,40
Exports (%)	13,51	13,07	14,97	14,78	12,54	–	–
Profits (%)	5,91	8,08	8,04	5,87	4,79	4,05	6,54
Number of firms (%)	5,21	5,21	5,23	5,27	5,18	5,03	5,19
Average number of employees (%)	8,10	8,78	8,96	9,05	8,72	7,73	7,95

* based on short-term statistics

Source: Author's calculation based on the Electronic Database of Statistical Office of Estonia (www.stat.ee)

Wood sector firms are more oriented towards foreign markets than Estonian firms in general (see also Table 9). This can be also seen from the results of the CIS4 survey, where 60.6% of the wood sector firms surveyed held EU or EFTA countries as their main market area. As most of the wood products are in the maturity phase in their product life cycle (Frühwald, Solberg, 1995) and the main export markets are growing at a slow rate, export competitiveness has so far been supported by the low labour costs and abundant supply of domestic wood resources. Rapidly growing labour costs, low productivity levels and strengthened competition from Asian countries have constantly been absorbing residual income[33] in the furniture industry even into the negative figures in 2005 (Varblane, 2006). The decrease in domestic wood supply under the conditions of expanding production capacities has led to a significant growth in roundwood imports (by 2005 net exports of roundwood were negative). Since the wood sector is basically the only sector in the manufacturing industries in Estonia that balances the negative foreign trade balance created by other industries, the

[33] This is the share of value added left after subtracting labour and capital costs, which can be used for investments in firm development.

dependence on wood of Russian origin and rapid price increases due to customs and other trade barriers could be critical for the further development of the sector.

Wood-related industries have also achieved higher productivity than the average in the entire manufacturing sector. The only exception here is the furniture industry, where the labour productivity level is below the average for manufacturing (Ukrainski, Vahter, 2004). A considerable amount of foreign direct investments have flowed into Estonian wood processing companies, but the share of foreign capital is still below the average level for the manufacturing industry. The superior productivity of foreign-owned companies over domestically owned firms in the wood sector is much lower than the average for Estonian manufacturing. Here again, the furniture industry is an exception, having greater differences in productivity between foreign-owned and domestic companies (Ukrainski, Vahter, 2004).

By looking at the data in Table 9, one can see that in the beginning of the period, the wood sector has grown faster compared to the rest of the economy; however, after 2003–2004, growth has slowed in sales turnover, exports and profits. This trend has been caused by both, increased labour and material costs and the deteoriation in the availability domestic wood. In all the above-described reasons, the pressure for innovative activities is rather strong. However, it also has to be noted that in those firms that are closely tied to the construction sector (window and door producers, wooden construction detail producers), the domestic market has become very attractive and an easily accessible fast growing market, where conditions were more favourable in terms of prices compared to export markets.

Innovation activities of wood sector firms

It has to be noted, that by studying CIS3 and CIS4 data, it can be concluded that innovative activities have intensified in 2004 compared to 2000. If CIS3, covering the years 1998–2000, reveals only 35.8% of innovative firms from among all wood sector firms, then CIS4 (2002–2004) reveals that innovative firms comprised 53.2%. One could consider one important reason for this being that the innovation awareness of the respondents has risen (because issues related to innovation are discussed more frequently in the community). However, the fact that on average the share of innovative firms has been growing faster than in the manufacturing industry is even more remarkable (where the growth in the same period was from 38% to 48%). Similarly, the importance of firms with internal R&D activities has also grown – in the period 1998–2000 such firms comprised only 26.8%, and by 2002–2004 already 39.1% of firms (in other manufacturing industries these figures were higher 46% and 62.3%, respectively)[34].

The study also reveals the increasing role of domestic firms in developing innovations. The role of firms has diminished in process innovations (from 11.6% to 6.1% in innovative firms), which is again different from the average in other manufacturing industries, where it has grown (from 11.3% to 13.9%). The main sources of knowledge are suppliers of machinery, equipment and materials, whose role has also grown (see Table 10). As before, the role of universities and research institutions remains minor in supplying knowledge for innovation.

Table 10. The average scores for the sources of knowledge used for innovative activities

Sources of knowledge (as mean of the following estimates: 3=high relevance, 2=medium relevance, 1=low relevance, 0=not used)	Wood sector		Other sectors of the manufacturing industry	
	1998–2000	2002–2004	1998–2000	2002–2004
The firm itself	1,84	–	1,89	–
Concern	0,59	–	0,54	–
The firm or the concern	–	1,68		1,95
Suppliers	1,61	1,84	1,55	1,69
Customers	1,56	1,58	1,64	1,65
Competitors	1,24	1,18	1,07	1,16
Consulting firms	0,33	0,44	0,43	0,53
Universities	0,13	0,20	0,34	0,37
R&D institutions	0,12	0,15	0,13	0,26
Conferences, journals	0,69	–	0,98	–
Fairs, exhibitions	1,35	–	1,33	–
Conferences, fairs	–	1,53	–	1,43
Journals	–	0,79	–	0,99
Industry associations	–	0,36	–	0,47

The Estonian wood sector has received significant foreign investments, but the constant pressure to upgrade is encouraged rather by export demand, but to some extent also due to FDI, and this has caused quite rapid technological development in Estonian wood sector firms. Product and process innovation are closely connected in those industries – incremental innovations in production processes add significant new characteristics to the end products (Palmberg,

[34] It has to be noted here that the data from the CIS surveys is quite different from official R&D statistics, where the data reflects only casual R&D activities or their complete absence in wood and paper industries.

2000; Laestadius, 1998). Therefore, the share of firms performing both types of innovation is rather high – 34.8% of all innovative firms[35].

Expenditures on purchasing machinery, equipment and software are the largest in the wood sector (these are on average more than twice as large as in other manufacturing industries). This is also one reason why total innovation costs are almost twice as large (the average wood sector firm spent 7.6 million kroons, the median firm spent 1.2 million kroons in 2004 on innovative activities; respective indicators for other firms in manufacturing industry were 3.9 and 0.7, respectively). Even more remarkable is the growth in innovation expenditures – according to the data in the earlier CIS, four years ago the average expenses in wood sector were significantly lower compared to other sectors.

Table 11. The average scores for the impact of innovative activities

The impact of innovative activities (as mean of the following estimates: 3=high relevance, 2=medium relevance, 1=low relevance, 0=not used)	Wood sector		Other sectors of the manufacturing industry	
	1998–2000	2002–2004	1998–2000	2002–2004
Expanded nomenclature	1,63	1,63	1,88	1,54
Expanded market or market share	1,73	1,86	1,73	1,72
Improved quality	1,91	2,10	1,98	1,89
Increased flexibility of production	1,55	1,68	1,57	1,59
Increased production capacity	1,76	–	1,55	–
Increased productivity	–	1,83	–	1,27
Decreased labour costs	1,48	1,59	1,17	1,07
Decreased material costs	1,23	1,36	1,05	0,72
Improved environmental safety	1,08	1,24	1,10	0,69
Improved correspondence to legal norms	0,96	1,02	1,18	1,17

R&D activities have become continuous rather than occasional in wood sector firms (the share of firms with continuous R&D has grown 3.6 times compared to the earlier CIS, for comparison, in other sectors of manufacturing industry, they have grown 2.2 times). One can also say, that the results of those activities measured according to their impact on various performance indicators, have improved (see also Table 11). The innovations have mainly resulted in increased efficiency in production processes and improved quality of products

[35] Here, in process innovation only technological production processes are considered; the innovations in managerial and marketing processes are left out.

(the average assessment of the impacts is remarkably high compared to the previous CIS and other sectors).

At the same time, the main barriers to innovation are related to the lack of internal finances for innovative activities and the lack of competent personnel in firms (both barriers have been higher in the wood sector compared to other sectors during the longer period of time) (see Table 12).

Table 12. The average scores for barriers to innovative activities

The barriers to innovation (as mean of the following estimates: 3=high relevance, 2=medium relevance, 1=low relevance, 0=not used)	Wood sector		Other sectors of the manufacturing industry	
	1998–2000	2002–2004	1998–2000	2002–2004
High economic risks	0,88	–	0,97	–
High innovation costs	1,38	1,40	1,36	1,10
Lack of financing	1,67	–	1,48	–
Lack of internal financing	–	1,70	–	1,45
Lack of external financing	–	1,09	–	0,92
Organisational rigidities	0,54	–	0,50	–
Lack of competent personnel	1,28	1,54	0,91	1,24
Lack of technological knowledge	0,99	1,00	0,73	0,78
Lack of market knowledge	1,02	0,92	0,78	0,77
Lack of cooperation partners	–	0,78	–	0,69
Dominant firms on the market	–	0,98	–	1,00
Rigidity of legal norms	0,66	–	0,63	–
Lack of consumer demand	0,98	0,62	0,95	0,87
Risky demand	–	0,93	–	0,88
Lack of demand because of earlier innovations	–	0,54	–	0,91

The share of firms that received some form of public support for innovative activities has increased in 2002–2004 compared to 1998–2000 (12.2% and 1.5%, respectively). Financial support was largest for training, which is different from the other sectors in manufacturing, where the largest support was given to internal R&D activities and external R&D acquisition. Support for internal and external R&D was given to 35% of innovative wood sector firms compared to the 42.3% of firms in other sectors. The same figures for training activities are 42.9% and 30.8%, respectively. Public support for external knowledge acquisition has not been used by wood sector firms compared to the 21.2% of other firms in the manufacturing industry. At the same time, the share with such expenses is not different (among innovative wood sector firms 33.9%

and in other sectors 35.5%). Public support for marketing innovative products was received by 7.1% and for innovation cooperation also 7.1% of the innovative wood sector firms (the same indicators in other sectors are 32.7% and 19.2%, respectively).

The data from the innovation surveys show, that wood sector firms have responded to the changes in the conditions in regard to competitiveness in export markets, but also to the pressure from increased labour costs in the domestic market, by intensifying their innovative activities and increasing investments in new technologies. The strongest barriers to innovation that remain are the lack of internal finances and competent personnel, but also high innovation costs, and these are felt stronger compared to other manufacturing industries.

Changes in technologies and products in wood-related sectors

Each specific technology is characterized by technical, financial and environmental parameters. There seem at first sight no radical changes in wood technology in the last decade. For example, in forestry, tree harvesters and forwarders have basically been employed with automated control systems since the early 1990s (Blombäck et al., 2003). The first walking harvester was produced in 1995 and used in harvesting in Germany by 1997. In 2000, the unification of harvester and forwarder functions in one machine (harwarder) was accomplished (Kurvits, 2003). In the wood processing industry, sawmilling of logs and computerized scheduling, multiple circular saws and edgers for the processing of small dimension logs were already introduced in the 1980s (ILO, 2001:49). Advanced pulp and paper mills with digital process controls for almost all of the production parameters with very low labour participation in the process have also been used since around the 1960s (Laestadius, 2000). Computer aided manufacturing systems (CAM), design systems (CAD) and automated coating systems have also seen relatively moderate changes in recent years. Instead of radical changes, there have been constant incremental improvements of technological processes in the sectors under consideration. The analysis of case-studies by Palmberg (2002) reveals a very close interrelationship between product and process innovation. He finds that the incremental innovations related to sawing, gluing and jointing techniques in the gluelam timber industry have added considerable new characteristics to the end product. The same for pulp and paper industry technologies is shown by Laestadius (2000). However, these incremental changes in the processes have used the recent achievements in different "high-tech" sectors. The examples, where technological advances of other industries have been used to develop technologies in the wood sector are brought together in Table 13.

Table 13. Examples of technological advances in the wood sector

Underlying technological advance	Technology used in wood sector	Motives and results for wood sector
Mechanical, electronic engineering	Automation and control systems, valves, transmission systems, pumps, dryers for pulp and paper mills etc.	To develop new machine concepts, components, systems, equipment, tools aimed at optimising costs and improving environmental performance
Chemical engineering	Chemical modification of wood, fibre etc. Development of paints, adhesives etc.	New conversion techniques New application concepts New/improved produc quality
Biotechnology	Genetically modified wood Enzymes for bleaching processes	Better handling (storage, transportation) Higher product quality, some cost-cutting
ICT	Application software (GIS, MRP, TQM, CAPP, JIT, JIP etc.) Production systems (hardware) (CNC, CAM, CAD, FMS etc.)	Increased use of economies of scale processes Optimised service functions (KIBS, including logistics, e-commerce)

Source: Author's compilation using the example of Pavitt (2005)
Note: GIS – Geographic Information Systems, MRP – Manufacturing Resource Planning, TQM – Total Quality Management, CAPP – Computer Aided Process Planning, JIT – Just-in-time Production, JIP – Just-in-time Purchasing, CNC – Computer Numerically Controlled Machines, CAM – Computer Aided Manufacturing, CAD – Computer Aided Design, FMS – Flexible Manufacturing Systems.

As can be seen from the Table 13, the underlying technological advances are connected with chemical and mechanical engineering, but also with biotechnology and ICT. The latter covers a remarkably wide range of technologies used in the wood sector. As discussed by Schienstock et al. (1998:25), modern ICTs have different roles to play: they can function as tools, automation technologies and control devices, as organisational strategies and technologies, as a medium for connecting machines and people and finally as a process to be developed. Such technologies as ICTs are also called General Purpose Technologies, they introduce radical changes in many other technologies and are also generally seen to complement more skilled labour (see also Murphy, Riddell, Romer, 1998).

Traditionally, advances in the technological development of different sectors in the economy are assessed through R&D intensities. In forest industries, the R&D intensity and also respective educational level of employees is relatively low. The markets where wood sector firms operate are indicated as very competitive ones – where the appropriability conditions of technology and innovation are weak because in many cases the products are relatively easy to imitate, at least at first sight (Palmberg 2002:25). The depleted technological opportunities and saturated markets to a certain extent explain the low levels of R&D in these sectors. Most of the research for those industries is done by other sectors, such as equipment manufacturers or biotechnology firms. Often those firms are highly specialised, concentrated and operate world-wide (e.g. harvester and forwarder producers or paper mill equipment producers), so this means that the latest technology is available everywhere (ILO, 2001:50). State-of-the-art technology is diffusing to developing and transition countries via FDI, but not necessarily. In the literature (ILO, 2001), there are examples of larger firms in developing countries that do well without the help of that kind of foreign capital.

In addition to the process technologies used in production, many larger and more specialized firms in the forest, wood and paper industries are gradually converting to e-commerce because there are some real gains in terms of production and distribution costs through improved planning and management of the procurement processes, transport and storage. Deeper analysis for all different kinds of knowledge-intensive business services (KIBS) in the Finnish wood sector is given by Viitamo (2003).

The wood processing industry in Estonia has been constantly expanding – the first modern sawmills were built in 1995. From this point onward, substantial investments by sawmilling industries in new, modern and efficient technologies were made whereby productivity has increased along with employment, thereby securing a competitive position on domestic, but also on export markets. The sawmilling capacity was set up according to domestic felling volumes in late nineties. As domestic fellings have drastically decreased since 2000, the processing capacity has exceeded the supply of domestic roundwood and led Estonia to become a net importer in recent years. To overcome the shortage of raw material, investments were made in different value-adding technologies thereby enhancing the product and process innovation. This situation was also further accentuated by changes in the use of small dimensional roundwood (mainly pulpwood). Estonia does not have capacities for pulp production from pine, spruce and birch timber and therefore the pulpwood from these species is exported. In addition to sawmills, other innovative wood processing facilities were created, using small dimension roundwood (e.g. gardening and fencing products). (Teder et al. 2007)

Estonian wood and forest sector firms have advanced significantly in the last 15 years. At the beginning of the 1990s, technology absorption started (mainly in the form of technology imports that was also FDI-dependent), and had matured by 1995 (Kolk, 2003). Here strong information and technology flows can be observed from the forest clusters in Finland and Sweden, but also from the other Nordic countries. As can be generally concluded from interviews in

2003 and 2004, most of the larger companies entered into the adaptation phase (Agasild, 2003), but there were also some firms that innovated and created new products and technologies (Kuldkepp, 2003). The latter can be seen as being in the implementation technology phase (see Burgess et al. 1997 for more detail).

By looking at Figures 5, 6 and 7, investments in machinery and IT related systems show a generally increasing trend. Transportation machinery has been significantly improved in forestry, where it plays a crucial role in determining the productivity of the sector. From 1994 onward, modern tree harvesters and forwarders have been imported and today about 100 harvesters and 300 forwarders are harvesting about 40% of all fellings in Estonia. In 2002 (2 years after its launch), one harwarder was also employed in Estonia (Kurvits, 2003). In recent years, the capacity of all acquired machinery is way above local needs, and therefore harvesting services are also occasionally exported to other countries (Russia and Sweden). It is interesting to note that in addition to transport machinery, there has also been heavy investments in IT related systems in forestry compared to other sub-sectors.

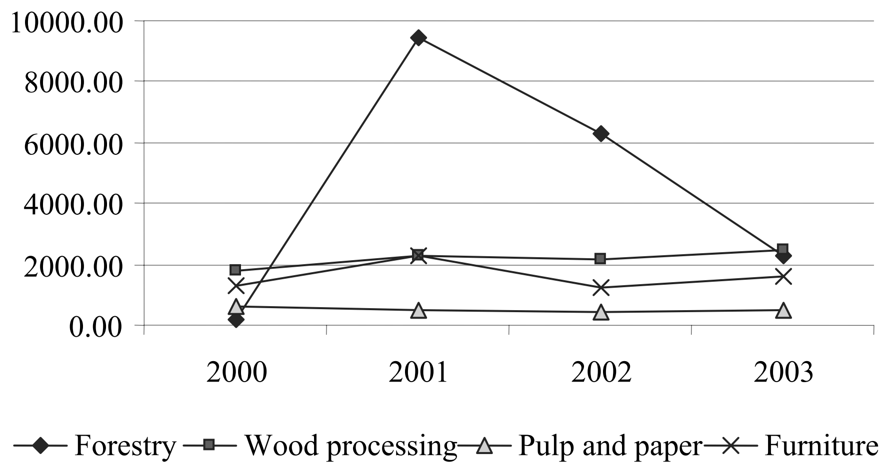

Figure 5. The dynamics of average investments into transportation equipment per employee (EEK, corrected with PPI) (Author's calculation based on Statistical Office ... (2006))

Investments in IT related systems is described in Figure 6, but can also be analysed at a somewhat later period, where it also shows a generally increasing trend. If we consider the intensity of IT related investments, then Estonian companies acquire these generic technologies less intensively. While Finnish wood industry companies have spent approx. 0.2–0.1% from their turnover on

IT related equipment in recent years[36], the Estonian figure remains lower in woodworking (0.05–0.08%) and paper industries (0.02–0.04%); in furniture industry it is at about the same level (0.1–0.2%), but considerably higher in forestry (0.3–0.4%)[37].

ICT connectedness is, however, underestimated only on the basis of analysing the direct expenditure on IT and related systems. ICTs are embedded in many other technologies heavily used in wood sectors (like modern tree harvesters or forwarders).

The observed dynamics of the technological investments (see Figure 4.2.3) in paper industries has been stable in recent years and more incremental in terms of machinery. Since the paper producing machinery is very expensive, some parts of the process are replaced with modern machines, combined with second-hand imported equipment and existing old technology (Botvinkina, 2003). The same has been revealed by other studies of pulp and paper industries (for Swedish paper industries see Rundh (2003)).

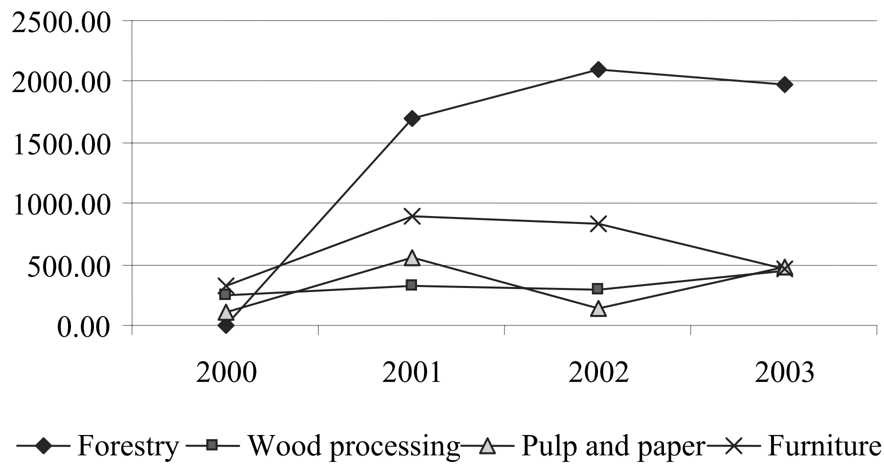

Figure 6. The dynamics of investments into computers and related systems per employee (EEK, corrected with PPI) (Author's calculation based on Statistical Office... (2006))

In wood processing, greater technological diversity can be found. Since acquiring several sawmills, Stora Enso has modernised most of its Estonian mills to the frontier of this technology (Stora Enso's..., 2006), which is some-

[36] The data stem from the Kuusisto (2005).
[37] Calculations base on the electronic database of Statistical Office of Estonia [www.stat.ee].

what reflected by the import data. In wood-based panels and furniture industries, modern factories are present alongside producers with old soviet-technology. By looking at general trends, however, the acquisition of technology has been quite extensive. As can be generally concluded from the interviews, most leading wood sector companies are in the adaptation phase in respect to imported technology (Agasild, 2003; Kolk, 2003), but there are also some firms that are creating novel technologies of an international standard (Kuldkepp, 2003). All these rapid technological changes have driven the companies to the situation, where they recognise the sudden need for skilled employees.

Machinery innovations are made mainly by suppliers, but sometimes also by users of machinery (wood sector firms) who used general-purpose equipment they had on site to improve/adjust the machinery of different producers from different time periods (most of the smaller firms admittedly have new machinery along with old and even sometimes self-built machinery. In addition, process innovations increased the range of products they could produce. The small refinements in individual processes can provide little value, but their collective impact on production costs can be large (Von Hippel 1988:81).

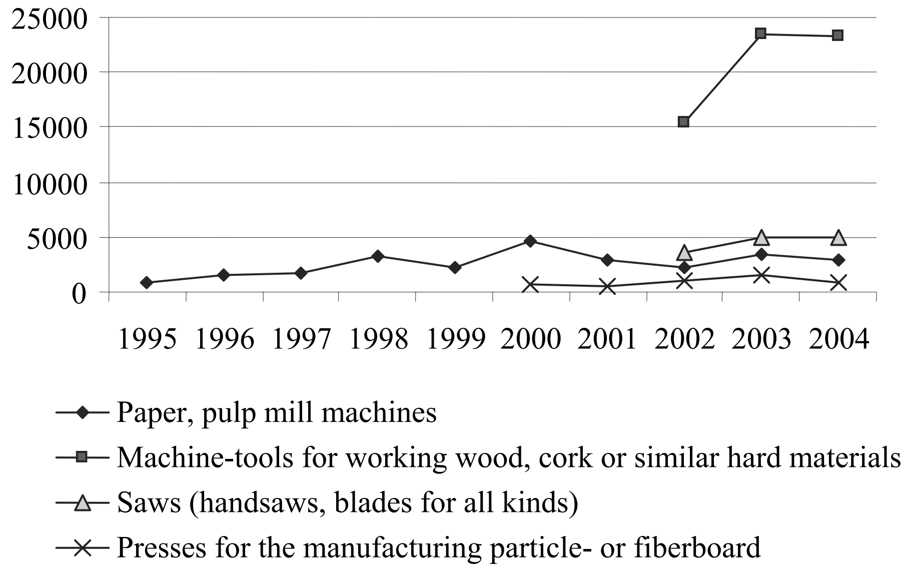

Figure 7. Imports of selected commodity groups (in thousands of USD; Source: UN Comtrade Statistics, 2006)

To sum up the technological changes, one can say that today's forest, wood and paper sectors represent a knowledge–intensive sector that continuously uses the latest developments in information and communication technology, process control and environmental technology to respond to demand in terms of properties and function, but also new applications and solutions. All these technological changes have been the result of the gradual improvement of technology, but have resulted in strong impacts on employment (ILO, 2001:49).

By looking at recent product innovations[38], one has to consider the fact that most of the firms interviewed are exporters; however, some of them in connection with intensified construction activities, reoriented their sales to domestic markets, where the marketing costs are lower and sometimes the domestic market is also more innovative [9, 11][39]. The share of exports in turnover is typically 80–90%, but it was revealed that the domestic portion of sales comprises mainly selling production residues or some indirect export through an Estonian distributor or agent, and in reality all end-products are exported [2,6,8]. In the sample, there are still some firms, who consider the domestic market as their target market and the reason behind this is mostly the orientation towards custom- or contract based work that requires close and frequent contacts between firm and customer [15]. However, there was no firm in the sample that would not export at all.

The traditional export markets for Estonian wood sector firms are in Europe (Germany and Scandinavian countries, most of all), but this situation is gradually changing, because several firms show a switch towards Spain and France in Europe [2]; additionally, firms with a more active marketing strategy are also selling in the growing Asian markets, where prices are better or simply, the risks associated with the concentration of the export market are minimised [5,14]. Here, the significant differences seem to prevail across sub-industries, Asian markets are not captured by furniture firms because their largest competitors prevail on these markets (here, one exceptional firm has been identified, who has a sister company in China and therefore respective export is possible) [3].

Some firms consider the domestic markets more innovative and demanding [1,9], and hence they frequently have to seek new products and solutions. Smaller adjustments in all products have to be made when entering any new market (new technical solutions, new standards etc) [1,8,9], however, very narrow segments can be identified, where the demand is in different countries [9,11]. The process of entering new foreign markets can be made much simpler for firms (especially SMEs) with the help of the public sector; for example, by

[38] Here the analysis is based on interviews conducted in 2006.

[39] Here, the path of several firms has not followed the traditional path of internationalization by which the firm starts from the domestic market and thereafter expands to foreign markets. Several firms were born as export-oriented firms.

making (and downloadable from the internet) the technical standards of all different countries publicly available or by simplifying customs procedures[40].

There can be two diverse strategies distinguished that are very different in terms of innovative activities, and both proven to be successful export strategies so far for wood sector firms:

1. Flexibility – all the products are produced to the client's specification, the products are very heterogeneous. This strategy is pursued more by SMEs that do not plan to expand considerably, because in large firms this strategy is not working [15]. With this strategy, every product is an innovation to a certain extent[41], (although most managers interviewed do not consider them as innovations) [14,15].

2. The development and exploitation of the firm's own (or concern's) trade mark for a product range with certain qualities is a strategy for larger firms and those with a more aggressive marketing strategy. These can be firms producing more exclusive and design-innovative products, but also firms producing traditional products that have achieved a certain knowledge or maturity on the market [5,9,10.]. In those firms with this strategy, the number of different types of products has also grown even if the main technical solution has stayed the same [4,8].

Stemming from the different strategies described above, the innovation processes are also different. In the case of a flexible strategy, every produced item is different in some respects, and therefore, the combination of all internal knowledge resources is needed to complete one single contract. There are firms collecting databases of technical assemblies to makie existing knowledge more easily exploitable and also in order to improve their products using smaller incremental solutions [2,11]. Because of the increased flexibility and complexity from complex technologies and materials, the number of technical specialists has been increasing in such firms [2]. This kind of strategy is sometimes prescribed also by the location; for example, woodworking firms located on islands have geographic limits to the expansion of their production capacities and also to their whole business strategy [14,16].

As competitive strengths, not only does price play a relevant role, but also quality, speed and reliability of delivery help to differentiate them from their competitors[42]. Regarding quality, there are different requirements on different

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40 The fees required for standards especially hinder SMEs with a flexble production strategy that produce many different small details.

41 Following Schumpeter's concept, further developed by Henderson and Clark (1990), by which the innovation is seen also in recombination with existing products and technologies to create something new.

42 It is very difficult to make some generalisations, because the relative importance of different factors according to the interviewed managers varies. They all consider a set of factors that are relevant for competition, but the relative importance is different depending from the firms strategy, market and product specificity.

markets. If for example, wooden houses require similar quality compared to the world's leading producers, but for garden houses, a certain accepted quality level exists that secures the normal life-time of the product and above which the consumers are not willing to pay [4,5]. There can be differences in the competitive positions seen in different sub-industries – in the furniture industry, one can see that the larger firms are falling in profitability (that is also revealed in aggregate industry statistics); however, smaller, but rapidly growing firms that have found themselves a niche, are showing increasing profitability. In order to stay competitive, one has to differentiate and identify some niche on the market. There can be changes along the value-chain in the furniture industry identified by moving towards distribution and assembly, thereby only the core-production is kept and the rest is bought from other firms in order to be more flexible by satisfying consumer demand [1,8]. Concerning other sub-industries – wooden houses, for example – recent development points towards improving and securing quality via complementary services (e.g. construction on site) [2].

By summing up all the factors that influence the firms on the basis of their product innovations, one can say that by looking at pure product innovations, quality and precision has improved and the designs have changed (mainly in the furniture and wooden house industry). There are different complementary changes that are as relevant as the product (distribution, marketing, pricing strategy etc.).

2.1.3. Use of knowledge sources in Estonian wood sector firms

An analysis of the innovation sources (the sources of the innovation–related information) in the CIS3 survey revealed that the sources had relative similar importance according to the share of firms that used them (within the company (28.4%), suppliers (26.4%), customers (25.8%), competitors (24.9%), exhibitions (24.6%)). Such innovation sources as universities and other non-profit R&D institutions scored at 3.7% and 2.9%, respectively. The importance of innovation sources was assessed as the highest by the users of the concern (55.2% of users of this innovation source) and as the lowest (76.9%) by the users of universities as the source of innovation.

When looking at formal cooperation activities and informal knowledge exchange (Figure 8), one can see that formal cooperation is lower compared to informal knowledge exchange, which was also identified in the study by Faulkner et al. (1995). The difference is the smallest on the basis of public sector research, consultants and firm cooperation, the relations with which are more likely to be formalised.

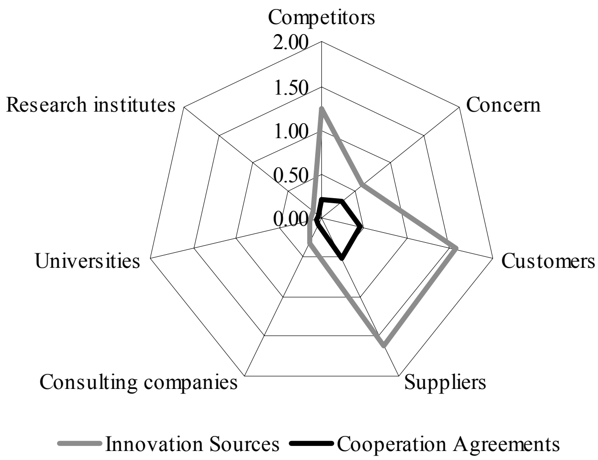

Figure 8. Average scores for using the knowledge sources and having cooperation arrangements according to the CIS 3 survey[43]

It is interesting to note that in business knowledge sources, most knowledge flows in from abroad, the importance of domestic sources becomes evident in public sector research, but also on the basis of consultants. Unfortunately, such comparative schemes cannot be constructed for CIS4 data, because of changes in methodology.

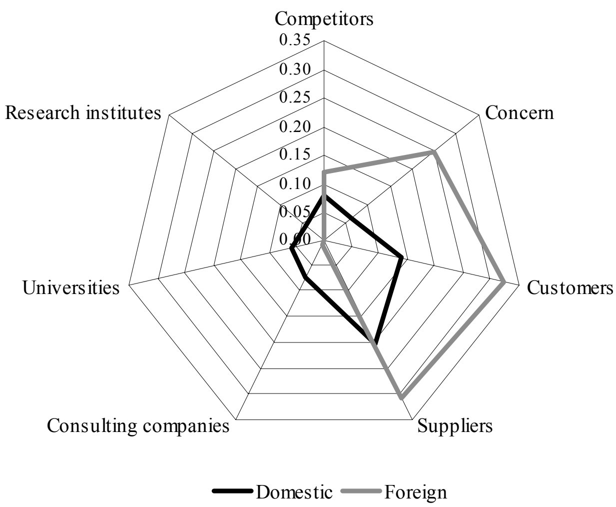

Figure 9. Average scores for cooperation on the basis of the location of cooperation partner according to the CIS 3 survey.

43 The methodology for calculating the both average scores is same as in Table 10.

The study presented in this research concentrates mainly on the Estonian wood sector, but in this sub-section in order to have some international comparison, the same industries in Finland are analysed. There are several reasons for comparing Estonian and Finnish wood and forest industries. Forestry provides one of the few renewable resources in both countries; and therefore the forest, wood and paper industries have always played an important role in both economies. The Finnish forest cluster is considered to be one of the leading forest clusters in the world[44], and could therefore be taken as a benchmark for Estonian industries. Additionally, wood sectors in both countries have strong connections with each other through FDI, supplier relationships (machinery) and customer relationships (raw materials, but also finished products)). Finally, the cultural similarities in terms of core values and cooperative styles between Estonian and Finnish managers are found to be rather considerable (Nurmi, Üksvärav, 1994). The differences between the countries stem from their different developmental levels, from the relative importance of the sub-sectors in the cluster (in the Finnish wood cluster, the pulp and paper industry is a driver, whereas in the Estonian case this sector plays a minor, albeit, expanding role) and from the extent and quality of the national innovation system infrastructure in both countries. The relative importance of different innovation sources in comparison with the Finnish forest cluster is illustrated in Table 14.

Table 14. Comparison of the relative importance of innovation sources in Finnish and Estonian wood-based industries[45].

Innovation source	Paper Industry		Wood Industry	
	Finnish	Estonian	Finnish	Estonian
The company itself	2.42	2.43	1.82	1.81
Competitors	1.42	1.14	1.43	1.31
The parent company	1.11	1.00	0.61	0.57
Customers	2.11	1.43	1.75	1.57
Suppliers	1.53	1.71	1.68	1.60
Exhibitions	1.26	1.29	1.50	1.35
Conferences and meetings	1.16	1.00	1.18	0.86
Consulting companies	0.79	0.29	0.82	0.33
Universities	1.21	0.29	1.07	0.12
Research institutes	1.00	0.12	0.89	0.13

Sources: Viitamo (2001), own calculations

[44] Its historic development has been described in Blomström and Kokko (2002).
[45] The Finnish data are from 1999 (Viitamo 2001), the Estonian data from CIS3 1998-2000. In both cases, the respondents were asked to rank alternative innovation sources by importance (0 = no importance, to 3 = very important). In the table are shown mean scores of the responses. The wood industry here also involves furniture manufacturing.

When discussing the Estonian paper industry, one has to take into account that the industry is relatively small (here only 6 companies were used for calculating the mean scores) and extremely concentrated with two major companies. Looking at general information intensity, one can see that Finnish paper companies rely more on universities and research institutes. Here too the tremendous size differences between Estonian and Finnish paper companies play a relevant role, but additionally, the weakness of respective institutions is a more general problem for the whole sector as stressed by the industry leaders (Botvinkina, 2003). The smaller weight of innovation sourced from the concern or mother companies for Estonian firms can be explained at least in one case by the fact that the mother company is not active in the field of paper production (since there are few companies in this sector, this could influence the mean significantly). In the case of supporting industries, Estonian paper companies rely relatively more on suppliers, while customers as an information source are less important.

In the case of wood industries, one can see that Estonian wood and furniture companies assess all information sources with lower intensity for innovation. The innovation sources that are almost non-existent for Estonian wood and furniture companies are universities and other research institutions (the respective means are 0.12 and 0.13). One explanation here is that the industry is absorbing modern technologies and is not using and creating new or novel knowledge. An additional explanation is that wood technology research and schooling is lagging behind actual industry needs. In fact, there are also hardly any pulp and paper technology or log house technology specialists educated at the tertiary level in Estonia. The research and development activities of those branches are extremely poorly developed as recognised also in developing strategies for the wood and forest sector (Ministry of Environmental…, 2003). This part of the knowledge system is very poorly developed so far and could hinder the development of the whole sector.

By taking the whole sector together, one can see from Figure 10 that the public knowledge base, but also consulting firms are used to a remarkably lesser extent compared to Finnish firms and this has not changed much in recent years (judging by the CIS4 data in Table 10).

The analysis showed that the importance of all innovation sources is assessed as being generally low in comparison with Finnish companies, which indicates that the intensity of the use of knowledge is lower in the Estonian wood sector. One reason for this could be the low absorptive and innovative capacities of Estonian companies; however, the other reason lies in the very different public sector R&D specialisation in these countries. The R&D specialisation of Finland is rather different with respect to wood industries compared to Estonia (this has been discussed more in detail in section 2.3.2).

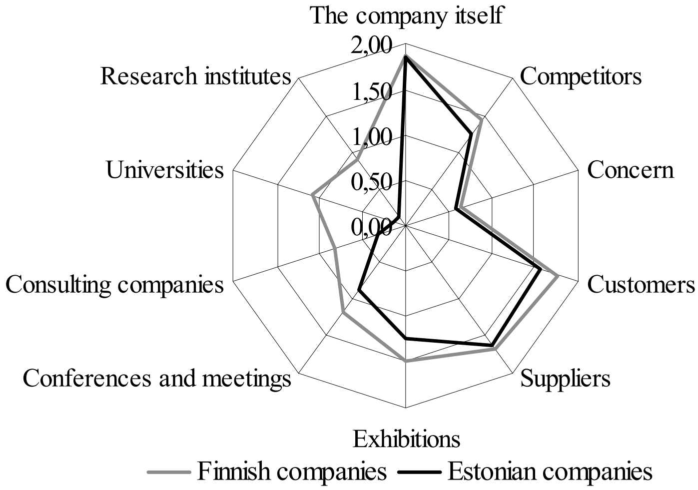

Figure 10. The average scores for innovation sources used in Finnish and Estonian paper, wood and furniture companies (Viitamo, 2001; author's calculations based on Innovation in … 1998–2000).

2.2. Innovation sources in Estonian wood sector companies

2.2.1. Research hypotheses

Considering the available data for testing the hypotheses, the compilation of the methodology based on theoretical studies, sectoral specificity and the methodology of the CIS is necessary. On the one hand, the literature is extremely rich concerning factors that could possibly influence the choice of knowledge sources, and this would make it possible to construct quite a number of specific research hypotheses. On the other hand, the CIS survey also offers a complex set of indicators that could all be used to test many of these hypotheses; however, not all of them would be equally relevant for Estonian wood sector firms in their current situation; and therefore, the most relevant hypotheses for wood sector firms are selected for empirical testing. The hypotheses initially designed on the basis of the literature and the availability of CIS data are presented in Tables 1–4 in Appendix 16. To construct the hypotheses, the interviews conducted with managers are used as a tool for pre-selection. In choosing the hypotheses for testing, the interviews are highly relevant because there is no comprehensive theoretical basis for selecting them. As the interview sample was designed to be biased towards larger firms (see also section 2.1.1 for a description of the sample), it is necessary to control the hypotheses on a more representative basis. Despite not formulating many of the interesting aspects brought out in the literature in the hypotheses, they are commented upon by presenting the empirical results.

The innovation processes in firms contain several stages (as for instance, the chain-link model of innovation described in section 1.1.1), and these stages can be measured in the CIS dataset via discrete events that describe different types of product and process innovations. Some stages are reflected more directly and can therefore also be tested for the theoretical framework used in this research, but not all. Similarly, some stages seem to be more relevant than others in the current stage of development in the Estonian wood industry. Problematic measurement issues are discussed according to the separate hypotheses below.

As the CIS methodology doesn't include questions about the sources and methods for obtaining new ideas for product and process innovations, this can be compensated for to some extent by looking at the changes in internal knowledge management (proxied by innovations in internal knowledge management) and external knowledge management (proxied by relational innovations). These processes should show whether the firm deals systematically with acquiring, selecting and maintaining new knowledge. As brought out by Faulkner (1995), new product ideas mainly emerge internally within the firm with only some external inputs from other firms (hypothesis 1 in Appendix 16); in addition, the consultants may distribute the new product ideas across the industry (hypothesis 2). In response to the critics of the above-mentioned proxy variables, one has to admit that they only reflect the search activities pursued by firms indirectly. The questions about knowledge sources for new product ideas, new markets or new applications would better describe the search activities also contributed by customers. Therefore, these hypotheses are left out from the final set of hypotheses. As the most important innovations based on the interviews (see Figure 1 in Appendix 15) are product and process innovations, service, design, organisational, logistics and marketing innovations were also analysed, but there was no basis for constructing wood-sector specific hypotheses. Therefore, hypotheses 12–14 in Appendix 16 were also left out from the final set of hypotheses.

The dominance of internal knowledge resources in innovation processes has been revealed in theoretical sections 1.1. and 1.2. As discussed in section 1.3.1, the importance of internal sources can vary across different sectors, but based on the interview results, there was no innovation indentified in wood sector firms that would rest on external sources without significant contributions from internal sources[46]. Although the question of the relevance of internal sources

[46] Here, the use of internal knowledge sources is directly included in the questionnaire in the CIS3 survey; however, in the CIS4 survey, internal sources are combined with the concern's sources making the testing difficult. The problem lies mainly in the fact that the concern's sources are assessed as being important for innovation only by concern

was not included in the interview questionnaire, it was described very well in question 15, where the firms were asked to describe their cooperation processes with partners. The typical answer to this question was that occasionally, if internal knowledge was not sufficient in the firm, external partners were contacted (74% of interviewees), two managers said that only internal knowledge was relevant for innovation (one manager alone said, "*Ourselves and Mighty God in Heaven /are responsible for all innovative activities in this firm/*" [14]). In addition, two out of five concern members in the sample recognised the other concern members as being the most important knowledge source for innovation. Therefore, initial hypotheses no 1,3,8 and 12 presented in Appendix 16 are combined in the first research hypothesis:

H1: The internal sources of the firm are the main sources of knowledge used for innovation processes

The internal knowledge sources of the firm cover the personal knowledge of the innovator or problem-solver and the collectively-held knowledge in the firm forming the knowledge base of the firm. Typically (as discussed in sub-section 1.3.1) the absorptive capacity of firms is mainly empirically assessed via expenditures on R&D activities. However, in wood sector firms, internal knowledge sources are mainly built up via practical training and learning from the experience gathered from using the equipment and materials and producing some specific products. But the R&D component cannot be ignored completely – it seems from the interviews that those firms who have directed their attention to at least some type of R&D activities (reflected by interview questions 1–3 and 5 in Appendix 13) and personnel training (question 17 in Appendix 13), were also more open to different kinds of external information. And is seemed not to matter how high the actual spending level was and how continuous these activities were (both aspects were not included in the questionnaire directly, but can be assessed from the questions that describe innovation processes – how large are the R&D-related projects the firm has undertaken in recent years and what is planned). Firms with more intensive R&D and personnel development activities can be expected to rely more on internal sources while innovating. But stronger internal sources enable the firm to absorb knowledge from external sources by creating a virtuous circle – internal sources are also used for cooperative innovation projects. This can be illustrated by several examples from the interviews. Although, there was no firm in the

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members, which also lowers the average relevance of the use of internal and concern sources in the CIS4 survey (see also Table 10). Therefore the use of internal and concern sources in models based on CIS4 data are expected to show weaker evidence for H1.

sample that didn't have any innovation activities, a clear pattern was seen of the variety of innovation activities (different types of innovations conducted at the same time) and partners used to conduct these innovations. As most of the firms did undertake process and product innovations, only some had "soft" innovations (26%), but they also tended to have slightly more cooperation with competitors or educational institutions. The typical knowledge shared with clients concerns product design and suppliers the technical details of machinery or materials. With other partners, there was a variety of knowledge shared (market information, know-how on equipment, certification, environmental standards, legislation, logistics etc). The second research hypothesis is based on the literature (see hypothesis 16, 25, 26 in Appendix 16) and interviews:

H2: The firms with stronger internal capabilities are more likely to use different kinds of external knowledge sources

The first two hypotheses were conducted for internal knowledge sources of the firm and their role in innovation processes. Besides internal sources, there is a variety of external knowledge sources, which can be used in innovation processes, but their specific role has to be tested in the case of the wood sector. As mentioned earlier, continuous innovation processes can be measured via discrete incidents of innovation. In the CIS questionnaire there are several different product innovations, but also process innovations identifiable, and some that are difficult to classify into either category. However, all these discrete incidents of innovation have relatively different importance for wood sector firms. As judged by the interviews, almost 63% of the interviewed firms conducted product innovations, but only 16% of the firms were involved in service innovations, which at the moment seemingly play a minor role for Estonian wood sector firms (see also Figure 1 in Appendix 15). From all process innovations, 79% of firms conducted larger innovations in technological processes (new machinery or equipment), and smaller improvements in technologies were made by all firms. In addition, innovations in organisational processes were carried out in 32% of firms, marketing innovations in 26% of firms and 16% of firms conducted innovations in auxiliary processes, mainly in the field of IT (only one firm admitted some innovations in logistics). Therefore, it would be meaningful to look at the external sources used for the main types of innovations – product innovation and technological process innovation.

In addition, according to the interviews the most relevant business partners for innovation were suppliers (90%), customers (86%) and competitors (directly or through industry associations) (63%). The other sources were mentioned only occasionally; although, for example attempts at cooperating with universities have been mentioned in many cases (53%), the cooperation was either too general and did not contribute to innovation or it was even refered to as a failure by half the managers. Therefore, from the construction of the research hypotheses, the other external sources are eliminated (and respective hypotheses 6, 7, 10, 11, 22–24, 39–43 in Appendix 16 are left out).

Customers are typically used to novel[47] product innovations because the firms with more sales from new-to-market products are expected to have more knowledge exchange with customers (this is found to indicate a strategic choice to innovate at high level and lower risks via cooperation (Tether, 2002; Hamel, Prahalad, 1989)). The recognition of the role of suppliers in product development along with customers is most interesting; however, not for wood sector firms. It seems that although product and process innovations are very closely related (as also recognised by 37% the managers interviewed, see also Figure 1 in Appendix 15), the knowledge sources used are different for those innovations. As most (63%) wood sector managers admitted about customer-driven product innovations in the last three years (see also Figure 1 in Appendix 15), they had to find technological solutions for the required new products themselves. The reason here is that in most cases the customers are traders or distributors with no technological competence in the field (therefore initial hypothesis 5 in Appendix 16 was rejected and not tested any further). However, since service innovation and design innovation (the latter could also indicate more a type of process innovation) are not very widespread across wood sector firms, the hypothesis is constructed only concerning product innovations, and service and design innovations are estimated as well and compared to identify possible similarities. The third hypothesis (based on hypothesis 4 in Appendix 16) is therefore:

H3: Customers are used to obtain knowledge for product innovations

Redesigning and producing activities are related to many processes in the firm (technological, but also auxiliary processes), which require internal sources, but also external ones. Technological innovation has been the most relevant type of innovation for Estonian wood sector firms (79% of interviewed managers revealed technological innovation in the past three years) and they admit the dominance of suppliers in support of the adoption of such innovations in their firms. Suppliers are used more in firms with substantial investments in new process technologies with the aim of diminishing the barrier of a lack of technological knowledge for adopting and implementing those new technologies.

[47] It has to be clarified here, that although the novelty aspect is to some extent measurable according to CIS data (by separating new to the firm and new to the market products), the interviews revealed that this is difficult in practice, because typical innovations were new to the domestic market but not new to the international market; however both markets were served at the same time (therefore, the novelty related hypotheses 30 and 40 in Appendix 16 are not tested any further).

Therefore, a lack of suppliers with suitable capabilities can be a hindering factor in supplier cooperation. Perhaps firms only narrowly targeted towards process innovations related to cost minimisation are expected to have less cooperation activities in general, except for with suppliers (Tether, 2002) that seem to be the most important knowledge source in process innovations.

According to the empirical estimation, innovations in the general organisation of work are estimated as well, but no hypotheses is constructed, because it is impossible to distinguish which activities these kind of changes concern the most (production, marketing, design) – these activities reflect all activities in the innovation chain[48]. In addition to technological processes, which are mainly supplier-driven, information sharing with suppliers is also found to be critical in the literature for coordinating work schedules, but consultants may also be used for all the above activities (however, the use of consultants was mentioned only by two managers, therefore this was not tested any further).

With regard to distribution and marketing, CIS enables us to analyse marketing and logistics innovations, the first of which is mainly connected to internal sources and customers as judged by the literature. Stank et al. (2001), showed that collaboration with external partners in the supply chain increases internal collaboration in turn improving the quality of services (logistics, for example). However, since such innovations do not seem to be important yet for wood sector firms (only 26% of interviewed firms were engaged in marketing and 5% in logistics innovations), hypotheses are not constructed. Therefore, the fourth hypothesis[49] chosen for testing is:

H4: Suppliers are the main source of knowledge for technological process innovation.

Hypotheses H3 and H4 dealt with the role of the main external knowledge sources in the most relevant types of innovation for the Estonian wood sector. The following hypotheses are selected to test factors influencing the choice of knowledge sources. It has to be noted that risk considerations were not included as a special barrier to innovation according to the interviewees (according to question 7 in Appendix 13), and legal barriers were also not recognised as being important (see Table 3 of Appendix 15); therefore, hypotheses 19 and 36 in Appendix 16 were withdrawn. Similarly, the existence of formal cooperation agreements was not relevant in cooperation (hypotheses 21 and 37 in Appendix

[48] The question was not clarified according to the interviews as well because the managers discussed extremely different innovations when responding to questions 3 and 5 of Appendix 13 (for instance, increasing general flexibility of organisation, structural changes in the organisation, strengthening some divisions, new IT-related solutions, changes in strategies, investments abroad, changing the target markets etc.).

[49] This hypothesis combines initial hypotheses no. 9 and 27 of Appendix 16.

16) and is therefore not tested any further. In addition, since most of the firms included in the interview sample were exporting firms, there is no basis for testing hypotheses 18 and 35 in Appendix 16.

One interesting aspect of knowledge exchange for innovation discussed in the literature is the role of concerns in knowledge dissemination within local economies. In the business literature of section 1.2, this role is mainly seen as positive for enhancing the capabilities of daughter-firms belonging to the firm. Concerning multinational companies, spillover literature indicates positive knowledge spillovers from multinationals into the local economy, but institutionalist literature argues that the multinationals produce negative effects by destroying the local networks and not diffusing their knowledge to the local economy. This question, although much discussed by the interviewees, was not clarified because on the one hand it seemed that the subsidiaries of foreign concerns (26% of the sample) indeed seemed to rely on internal knowledge and did not actively cooperate with the competitors. However, there was another type of firm in the sample (namely domestically owned, which had subsidiaries in Estonia as well as abroad) comprising also 26% of the interviewed firms, who were typically very active in collaborating with competitors. Therefore, the question has to be tested via the fifth hypothesis[50]:

H5: Concern members use competitors less as knowledge sources for innovation.

The further hypotheses concerning those factors influencing the choice of different knowledge sources have to be drawn mainly from business and organisational literature. From the discussion in section 1.2.2, one can see that there are several factors that can have a similar influence on knowledge exchange, but also those factors that are source-specific. As discussed in section 1.2.1, the size of the firm clearly influences the choice of knowledge sources; however, the direction of impact is not determined in the theory (although a positive impact seems more commonly agreed). While smaller firms are in need of external knowledge because of their lack of resources, larger firms are better equipped with financial and human resources to obtain external knowledge (see also the discussion in Tether, 2002). At the same time, larger firms possess more internal knowledge resources that they can develop and use for innovative activities, but the various organisational barriers and other barriers may be larger. Firms with higher R&D capability should be able to use both, internal and external sources more, but those with higher personnel or organisational barriers are discouraged from doing so. As most of the firms in the CIS database are SMEs, a hypothesis concerning size was not constructed (hypothesis 15 in Appendix 16 was skipped).

[50] This reflects also the hypothesis no. 34 in Appendix 16.

The public sector research base can be accessed more easily by firms with more internal R&D activities and can be used for training as well as for obtaining market and technological knowledge. As in Estonia, the public sector reseach base is hardly used (26% of interviewees mentioned some kind of contacts, although in most cases not innovation-related); the respective hypotheses are not constructed for further testing.

Before discussing the relevant barriers for wood sector firms, a methodological difficulty has to be discussed. By considering the barriers for innovation, some problems with interpreting CIS methodology arise. Typically, in the literature the constraints are expected to provide an incentive for firms to cooperate or look for information outside the firm in order to reduce barriers to innovation (Belderbos et al. (2004), Tether (2002)). However, since the answers given to the questionnaire reflect the same two-year period, it is possible that the recognition of the barriers can also reflect the firms' barriers from the activities on the same period and the incentive to find solutions in a later period. In this study, two groups of barriers to innovation are considered to be important for wood sector firms (see also Table 3 in Appendix 15).

There seems to be acceptance in the literature (see also sections 1.2.1 and 1.2.2) that external knowledge sources are sought if internal sources are not sufficient for innovation activities. However, financial barriers discourage the use of such external knowledge sources requiring formal contracts to acquire the knowledge needed. In contrast, by using suppliers, customers and competitors, the financing barriers shouldn't count as much because the knowledge is exchanged more via informal contacts that are not as costly as engaging for instance, consultants. The knowledge exchange with business partners typically arises from business transactions (purchasing goods or technologies) and in the case of severe financial constraints, information exchange with such business partners can be discouraged as well (if such transactions are influenced by financing barriers). Quite many managers recognised that finance-related barriers constrain their innovation activities, although in most cases they recognised that external funding was easily obtainable (except for one firm, who suffered losses in recent years). Therefore, financial barriers in general are expected to discourage the use of external knowledge sources[51]:

H6: Financing barriers for innovation discourage the use of external knowledge sources.

The second factor, being even more relevant (judged by the interview results, see also Table 3 in Appendix 15), concerns the knowledge-related barriers to

[51] As stated also in initial hypotheses 20 and 39 in Appendix 16.

innovation. Knowledge related barriers can emerge from difficulties in finding suitable personnel, but also from internal and external knowledge management difficulties. Therefore, several initially constructed hypotheses are combined (hypotheses 17, 28, 29, 32, 33, 38 in Appendix 16). It is commonly agreed in the literature discussed in section 1.2.1, but also among the interviewees that if a firm's internal knowledge is not sufficient, external sources are used for innovation. As this is most often done when some problems with technology or materials emerge, this is expected to have an influence on the choices of the same period and therefore:

H7: Knowledge-related barriers for innovation encourage the use of external knowledge sources.

Individual sources of knowledge can also complement (or substitute) each other. As most of the literature in 1.2.1 argues in favour of the complementarity of internal and external knowledge sources, there is literature reviewed in 1.3.2 that finds interesting evidence that in some cases, such as in the case of low-tech SMEs (see Baardseth et al. 1999 study), public sector R&D can be a substitute for internal R&D activities assuring a critical amount of R&D for those projects that are considered too risky or expensive, in this way firms suppliment their R&D via partnerships with public research institutions (Vavakova (1995)). The interview results strongly support the complementarity hypothesis (see the discussion of H2); therefore, the contradictary hypothesis 41 in Appendix 16 was rejected. The eighth hypotesis is therefore:

H8: External knowledge sources complement a firm's internal knowledge sources.

Generally, the vertical interaction in the value-chain is supposed to complement the use of other external knowledge sources, but universities and public R&D institutions can be seen as substitutes to some extent offering similar knowledge. This can stem from differences in research systems. As Mason et al. (2004) find by analysing the differences in French and British research systems, the French firms tended not to collaborate with universities, but had close involvement with public laboratories, while the British firms were more engaged with university contracts. However, Estonian wood firms did not cooperate with universities for innovation projects; therefore, the hypotheses concerning universities and R&D institutions were not separately tested. There was a joint hypothesis covering 42–44 in Appendix 16 formed instead as follows:

H9: External knowledge sources complement the use of other external knowledge sources

It has to be noted that the analysis of the complementarity and substitutability of various knowledge sources is still underdeveloped in the literature, and therefore, the hypotheses constructed remains quite general, based on existing literature, but more interesting and unexpected results can be seen in the empirical section.

2.2.2. Use of knowledge sources in the innovation processes of firms

In order to test hypotheses H1, H3 and H4 stated in section 2.2.1, for each innovation activity, a binary logit model is constructed, whereby I want to model the specific choice behaviour explaining it using a set of explanatory variables. The dependent variable in the models has two values: 1 – if the type of innovation was carried through and 0 – if not. The probability of conducting the respective type of innovation is p and the probability of not conducting this type of innovation is 1-p. To estimate the model, the maximum likelihood method is used. The likelihood function estimated has the following form (assuming linearity in parameters, but not equivalence in attributes or variables (Ben-Akiva, Lerman 1985:63)):

$$L = \beta_0 + \beta_1 X_1 + \ldots + \beta_i X_i \cdot \qquad (1)$$

The link function estimated is: $\eta = \ln \frac{p}{1-p}$, where: $p \in [0,1]$, $\eta \in [-\infty, \infty]$ (2)

From the (2): $\frac{p}{1-p} = e^{\beta_0 + \beta_1 X_1 + \ldots \beta_i X_i}$ and (3)

hence: $p_i = \frac{e^{\beta_o + \sum \beta_i X_i}}{1 + e^{\beta_0 + \sum \beta_i X_i}}$ (4)

is the logistic function (Aldrich, Nelson, 1984:32). This function is continuous and can take values from 0 to 1. If we indicate $\beta_0 + \sum \beta_i X_i$ with Z, we can say, that the function is 0 when Z approaches negative infinity, and 1 if Z approaches infinity, in between those values the function grows monotonically. The theory underlying the decision deals with a single firm, whose preferences or tastes are implicitly contained in the form and parameter estimates of Z.

The method of maximum likelihood is based on the choice of the regression coefficients that maximize the likelihood that the respective set of choices is obtained. The function under maximization is as follows (Ben-Akiva, Lerman, 1985: 84–85):

$$\ln L = \sum_{i=1}^{n} \left[Y_i \ln p_i + (1 - Y_i) \ln(1 - p_i) \right] \quad (5)$$

The independent variables; that is, the factors that influence the probability of choosing one specific innovation source are also formed considering the questionnaire and our particular interest in the wood sector. From the full set of individual variables only those in the final models that changed the likelihood of the wood sector model (choosing the respective information source) by more than 0.01% are considered (for this purpose, the backward stepwise method in SPSS is used).

In order to assess whether wood sector companies behave differently in respect to innovation activities (stemming from the provision of different resources, the competitive environment, demand conditions or other industry specifics) a likelihood ratio test is conducted that identifies the differences between the estimated coefficients across sectoral segments. This procedure was originally designed by McFadden, Tye and Train (1977). In order to determine whether wood sector choice factors could be generalised to other sectors in the economy; that is, whether other sectors have the same estimated parameters in the choice equations, the following steps were undertaken:

1. The data was classified into segments according to whether it belonged to the wood sector (wood, paper and furniture industry) or not.
2. Subsequently unrestricted models were estimated according to both segments described above.
3. The restricted model was estimated with the same specification (all sectors).
4. The hypothesis that the estimated parameters are the same across the different sectoral segments is tested, hence the null-hypothesis is as follows: $H_0 : \beta^{wood \cdot sector} = \beta^{other \cdot sectors}$, where βg are the parameters for sectoral segment g (here: segments are the wood sector and other sectors).

The null hypothesis is rejected if:

$$-2(L_N(\beta) - \sum_g L_{N_g}(\beta^g)) > \chi^2((1-\alpha), df) \quad (7)$$

where:

$L_N(\beta)$	– maximum likelihood of the restricted model
$L_{N_g}(\beta^g)$	– maximum likelihood of the model for industry segment g
df	– degrees of freedom = difference in # of parameters between models $= (\sum_g K_g) - K$
α	– level of significance

The following variables are entered in the final models:

1) Attributes of companies:
   Lnempl: the logarithm of the number of employees in 2004;
   Export: share of exports in turnover in 2004;
2) Monetary inputs on innovation activities:
   Totalinnocosts: the share of expenditures on all kinds of innovation activities in turnover in 2004;
   Intramural costs: the share of intramural R&D expenditures (including investments) in turnover;
   Extramural costs: the share of extramural innovation expenditures in turnover;
   Machinery: the share of expenditures on machinery, equipment and software (excl. those purchased for R&D activities) in turnover;
   Knowledge costs: the share of expenditures on external knowledge acquisition in turnover.

3) Knowledge sources used by firms. All these variables take 4 values (0 – not used, 1 – low relevance for innovation, 2 – medium relevance for innovation, 3 – high relevance on innovation):
   i_internalconcern: sources of knowledge within the firm or concern;
   i_suppliers: sources of knowledge from suppliers of equipment, materials, semi-finished products or software;
   i_customers: sources of knowledge in clients or customers;
   i_competitors: sources of knowledge in competing firms or firms in the same economic sector;
   i_consultants: sources of knowledge in consulting firms, commercial labs or private R&D institutions;
   i_universities: sources of knowledge in universities or other institutions of higher education;
   i_RDinstitutions: sources of knowledge in public R&D institutions;
   i_conferences: sources of knowledge in conferences, fairs, exhibitions etc.;
   i_journals: sources of knowledge in scientific, trade or technical journals;
   i_associations: sources of knowledge in industry associations or guilds.

The models are constructed for the following activities, which can be regarded as part of the innovation chain (see figure 1), but also as separate innovation activities:

1. *Prodinno:* binary variable (=1 if the firm implemented a product innovation, which means a good that is either new or significantly improved with respect to its fundamental characteristics, technical specifications, incorporated software or other immaterial components, intended uses, or user-friendliness);
2. *Servinno:* (=1 if the firm implemented a service innovation, which means a service that is either new or significantly improved with respect to its

fundamental characteristics, technical specifications, incorporated software or other immaterial components, intended uses, or user–friendliness);

3. *Procinno:* binary variable (=1 if the firm implemented a process innovation, which includes a new and significantly improved production or processing technology. The outcome should be significant with respect to the level of output, quality of products or costs of production and distribution).
4. *Loginno:* (=1 if the firm implemented a process innovation, which includes new and significantly improved methods of procurement of materials, supplying services and delivering products. The outcome should be significant with respect to the level of output, quality of products or costs of production and distribution).
5. *Auxillinno:* (=1 if the firm implemented a process innovation, which includes new and significantly improved methods of maintenance, procurement, accounting or IT. The outcome should be significant with respect to the level of output, quality of products or costs of production and distribution).
6. *Managinno:* (=1 if the firm implemented a process innovation, which includes new and significantly improved methods of knowledge management for better internal use or external acquisition of information, skills and knowledge).
7. *Workorginno:* (=1 if the firm implemented a process innovation, which includes new and significantly improved methods of organising work within the firm, e.g. in management structures, mergers of sub-unites, integration of activities etc.).
8. *Relationinno:* (=1 if the firm implemented a process innovation, which includes new and significantly improved ways in relations with other firms or institutions, e.g. formation of an alliance, partnership, purchasing of services, subcontracting etc.).
9. *Designinno:* (=1 if the firm implemented a marketing innovation, which includes new and significantly improved methods of design or packaging. This doesn’t include routine or seasonal changes.).
10. *Marketinginno:* (=1 if the firm implemented a marketing innovation, which includes new and significantly improved methods of sales or marketing, e.g. internet-sales, sales preference, direct marketing, selling licences).

Table 15. Log-likelihoods of the estimated binary choice models constructed for CIS4 data

LNg(βg) in models	All sectors	Wood sector	Other sectors	df
Product innovation*	–716.629	–83.488	–622.61	6
Service innovation*	–640.1	–36.5195	–582.902	4
Process innovation*	–684.185	–79.568	–596.364	7
Logistic innovation	–449.237	–49.0045	–398.844	3
Auxiliary innovation*	–693.581	–81.6055	–608.938	4
Knowledge management innovation*	–844.384	–90.4015	–749.669	4
Work organisation innovation*	–968.744	–110.675	–852.71	6
Relational innovation*	–839.977	–94.109	–745.334	3
Design innovation*	–720.349	–84.6295	–635.166	2
Marketing innovation*	–723.158	–71.6515	–645.37	4

* Models where the null-hypothesis was rejected at 5% level

The results of the log-likelihoods of the estimated models are shown in Table 15 indicating that the segmenting of the firms according to industrial sectors is meaningful for all innovation types and the use of knowledge is sector-specific (different in the wood sector compared to other sectors in the economy).

Table 16. Product innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
i_internalconcern	0.366***	0.063	0.365*	0.202	0.388***	0.068
i_suppliers	0.176***	0.069	–0.030	0.246	0.176**	0.074
i_customers	0.524***	0.077	0.740***	0.264	0.516***	0.082
i_competitors	0.005	0.083	0.785***	0.263	–0.085	0.089
i_RDinstitutions	–0.420***	0.131	–1.603**	0.677	–0.361***	0.134
i_conferences	0.671***	0.079	0.501**	0.226	0.700***	0.087
ASC	–2.640***	0.119	–2.489***	0.335	–2.677***	0.129
–2LL	1433.258		166.976		1245.220	
Nagelkerke R2	0.462		0.571		0.455	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The hypotheses were tested by using separate models for each type of innovative activity. However, for the purposes of comparison the innovation types not directly related to the hypotheses were also estimated. Product innovations can be measured using several equations – product innovations (Table 16), service innovations (Table 17) and design innovations (Table 18).

Table 17. Service innovations in 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
i_internalconcern	0.906***	0.067	0.745***	0.298	0.918***	0.069
i_suppliers	0.095	0.068	1.005**	0.348	0.089	0.071
i_associations	0.048	0.101	–2.034**	0.999	0.081	0.104
Innovation costs	–0.017	0.038	–8.592	6.013	–0.016	0.590
ASC	–3.003***	0.138	–4.836***	0.846	–2.912***	0.142
–2LL	1280.200		73.039		1165.803	
Nagelkerke R2	0.291		0.347		0.306	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Product innovations have greater relevance for the wood sector compared to service innovations or design innovations. The latter is more relevant for the furniture and housing sub-industries. Internal and concern sources are used for both, product and service innovations, but not for design innovations, where external knowledge sources seem more relevant (see Tables 16–18). Customers as knowledge sources increase the likelihood of a product innovation, meaning that H3 is supported in Table 16. Suppliers are relevant for service and design innovations, but not for product innovations (see Tables 17 and 18). Public sector research-related sources (universities, R&D institutes, but also literature) are not used for product-related innovations in Estonian wood sector firms. Competitors are used for product innovations, but not for service and design innovations, and so the industry associations are not used. In addition, conferences are used for product innovation activities.

Market demand is considered to be the strongest driver of product innovations according to interviewed managers, and so it is held to be very important to first recognise an innovative idea on the market. Often, firms use information channels associated with firms belonging to the same concern for that purpose (mother companies and marketing related sister companies) [1, 6, 8, 10]. However, cases were identified where firms have strong cooperation links with agents or distribution firms, who help develop products, but also processes [7]. Typically, product innovation starts with an idea received from a client or a fair (included together with conferences in the model presented in Table 16), and is further realised within the firm by changing the current designs or production processes using internal as well as external knowledge sources (including manufacturers of semi-finished products, but also suppliers of materials, chemicals, details etc) [1,8,9]. Many firms prefer to be physically present on the (export) market, because the information stemming from the client might not pass the distributor and get to the producer [5]. Despite this, several firms have closed down their foreign affiliates because of high expenses [8, 15]; several of them have been using modern ICTs in order to be present (virtually) on foreign markets thereby avoiding the costs of creating an affiliate [9].

Table 18. Design innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
i_suppliers	0.612***	0.054	0.689***	0.166	0.605***	0.058
ASC	–2.288***	0.100	–2.577***	0.333	–2.255***	0.105
–2LL	1440.697		169.259		1270.331	
Nagelkerke R2	0.121		0.143		0.119	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Taste/design differences are recognised only in products where design plays a dominant role, as in wooden houses or furniture [2, 3, and 8]. SMEs with flexible production systems allow the customer to do the designing job and create a technical solution by themselves [2]. The other way used by large firms is to produce the standard product and finish it specifically to the tastes of every single market, and add respective accessories [3]. However, some firms still produce market-specific products [8]. Larger concerns in general use the market competence of concern members located in specific markets (often also respective trade marks) by selling the products of different sister companies [5]. It is interesting to note that in some wood-related branches that are sensitive to fashion changes (e.g. the furniture industry), the innovation can also be a revived old style that for a specific firm in the sample meant the re-establishment of an old technological set-up [8].

Table 19. Technological process innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
lnempl	0.178***	0.065	0.406**	0.202	0.145**	0.069
i_internalconcern	0.494***	0.060	0.457***	0.173	0.524***	0.065
i_suppliers	0.544***	0.068	0.744***	0.214	0.511***	0.072
i_consultants	0.155	0.099	0.929**	0.419	0.137	0.104
i_universities	–0.131	0.112	–1.944***	0.667	–0.040	0.114
i_conferences	0.457***	0.075	0.637***	0.208	0.414***	0.081
ASC	–3.519***	0.266	–4.511***	0.902	–3.422***	0.279
–2LL	1368.37		159.136		1192.728	
Nagelkerke R2	0.430		0.560		0.417	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The conditions on various end-product markets are very different in terms of competition and price mechanisms. Generally, the target markets grow slowly or are stable, and the profit margins are not high. Judging by interview results, those firms that have found a niche (in terms of product specification, distinct technology or larger flexibility) have been more successful and are not competing directly with stung Scandinavian producers [2,7].

Table 20. Auxiliary process innovations in 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	Bi	S.e.	βi	S.e.
i_internalconcern	0.549***	0.060	0.496***	0.175	0.553***	0.064
i_suppliers	0.705***	0.064	0.817***	0.201	0.705***	0.068
i_universities	0.030	0.096	–0.825*	0.481	0.060	0.100
ASC	–2.822***	0.125	–3.035***	0.391	–2.804***	0.133
–2LL	1387.161		163.211		1217.876	
Nagelkerke R2	0.359		0.341		0.366	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The innovations in different processes are modelled in this study using several aspects – technological or production process innovation (Table 19), auxiliary process innovation (Table 20), work organisation innovation (Table 21), logistics innovation (Table 22), marketing innovation (Table 23), knowledge management innovation (Table 24) and relational innovation (Table 25). As the technology-related process innovations are currently most relevant for the Estonian wood sector, hypothesis H4 was constructed only for this kind of process innovation, and one can see from the tables that H4 has found supporting evidence. Suppliers contribute positively to technological process innovations, but in addition also to auxiliary process innovation, knowledge management and marketing innovations, meaning that the role of suppliers is even broader. Internal and concern sources are used in technological and auxiliary process innovations, but also relational innovations. It is interesting to note that customers are not used for any process innovations. Consultants contribute to technological process innovation, innovations in general work organisation, knowledge management and relational innovations. In addition, conferences contribute to technological process and logistics innovations and universities to innovations in work organisation. Competitors are used for marketing innovations.

Table 21. Work organisation innovations in 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	Bi	S.e.	βi	S.e.
Lnempl	0.428***	0.055	0.376**	0.170	0.446***	0.059
i_associations	0.039	0.106	–0.983**	0.482	0.109	0.111
i_suppliers	0.350***	0.052	0.540***	0.149	0.331***	0.056
i_consultants	0.532***	0.100	0.617*	0.353	0.507***	0.105
i_universities	0.223*	0.117	1.228*	0.765	0.191*	0.119
ASC	–2.797***	0.216	–2.973***	0.693	–2.817***	0.230
–2LL	1937.487		221.349		1705.419	
Nagelkerke R2	0.223		0.278		0.223	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

By analysing process innovations via the interview data, it is evident that the companies generally exploit the available imported technologies by combining them in the most profitable way, which demands practical engineering problem-solving on the part of engineers and technicians, but also shop-floor workers (in the early adoption phase even the management can be involved, as evidenced in some interviews). According to new technologies, it is considered to be important that the firm would be able to use these technologies effectively in connection with existing technology to train and motivate the employees respectively, because these technologies are very expensive and pay-off times quite long [1, 3, 5, 10, and 11]. Since the future sales volumes and required capacities are uncertain, the technology is usually bought using 20–30% spare capacity.

In most interviewed firms, the technologies are quite new – significant investments are made in less materially demanding and also less labour demanding machinery, but also in more mobile and flexible technologies (CNC-benches, camera-sorting equipment etc.) [1,2,3,4,5,6]. At the same time, it is characteristic in these sectors that brand new technologies are used with old ones [7,8,10] or even self-made equipment [4,14,15]. If generally the technology is considered to be of critical importance for the firm (primarily in increasing productivity), some firms in the sample still considered manual work very important and not replaceable to a significant extent with machinery [10,15]. There appear large differences in that respect between sub-industries (for example in sawmilling or veneer production compared to furniture production and the production of wooden houses) – in the case of uniform products, the substitutability with technologies is and remains larger [4,5,15]. In some branches it was revealed that the industrial demand for new technologies exists; however, the technology manufacturers have not reacted quickly enough, and therefore, the technologies are still too labour-intensive and such production is quickly transferred to countries with cheaper labour [8].

Logistics processes are described in the literature to be driven by internal knowledge and suppliers, instead customers and conferences seem to be relevant for Estonian wood sector firms. One reason for this could be the fact that most of the producers sell to large industrial clients (trading houses) dictating the logistics, which is different from the other industries analysed in the literature.

Table 22. Logistics process innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	Bi	S.e.	βi	S.e.
i_customers	1.599***	0.289	0.670	0.880	1.676***	0.303
i_conferences	1.032***	0.262	1.901**	1.020	0.990***	0.269
ASC	–3.902***	0.214	–4.192***	0.724	–3.892***	0.228
–2LL	898.474		98.009		797.688	
Nagelkerke R2	0.199		0.175		0.205	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Marketing activities were expected in the literature to be driven by customers, but the results in Table 23 show, that in the case of Estonian wood industries this is not true – suppliers and competitors are a driving force instead. The role of competitors has also been verified by the interviews, where close co-operation with competitors is admitted in the case of exporting firms.

Table 23. Marketing process innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	Bi	S.e.	βi	S.e.
i_suppliers	0.199***	0.065	0.359*	0.200	0.187***	0.069
i_competitors	0.507***	0.072	0.873***	0.231	0.478***	0.076
i_R&Dinstitions	–0.007	0.130	–2.428**	1.096	0.063	0.130
ASC	–2.254***	0.100	–2.935***	0.384	–2.193***	0.104
–2LL	1446.316		143.303		1290.740	
Nagelkerke R2	0.105		0.240		0.098	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Knowledge related process innovations were modelled using internal knowledge management (Table 24) and external knowledge management (Table 25). It has to be noted that such types of innovations were only occasional in Estonian wood sector firms.

The results show that internal and concern sources are used only for relational innovations and not for internal knowledge management innovations, but consultants are also found to contribute to both types of activities. However, in addition, suppliers contribute to knowledge management innovations probably indicating technological support (information and communication technologies) for internal knowledge management.

Table 24. Knowledge management innovations in 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Lnempl	0.323***	0.057	0.498***	0.187	0.319***	0.061
i_suppliers	0.461***	0.054	0.347**	0.167	0.485***	0.057
i_consultants	0.519***	0.083	0.832***	0.257	0.469***	0.088
ASC	–3.005***	0.228	–4.093***	0.810	–2.939***	0.240
–2LL	1688.767		180.803		1499.337	
Nagelkerke R2	0.208		0.251		0.207	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

By analysing all the estimated equations, one can see that in half of the equations the internal knowledge sources contributed to the different types of innovations. Although the most relevant types of innovations show supporting results, these are not convincingly strong evidence for accepting H1. Here the problem might lie in mixing internal and concern sources in one question. Recalling the assessment of general knowledge use by firms (see also section 2.1.2) in the CIS3 survey (where internal and concern sources were separated), the use of internal knowledge sources was assessed as being the highest, but the concern sources were assessed to be lower in general. By mixing these sources in one question, the scores have fallen in the CIS 4 survey, although some other indicators in the survey reveal that the firms have been working out the innovations increasingly by themselves and the share of concern-driven innovations is decreasing (actually, in one interview, the concern membership has been held as a discouraging factor keeping back the company's development) [6].

Table 25. Relational innovations in 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
i_internalconcern	0.416***	0.049	0.511***	0.149	0.404***	0.052
i_consultants	0.607***	0.081	0.608***	0.241	0.607***	0.086
ASC	–1.932***	0.090	–2.187***	0.274	–1.898***	0.095
–2LL	1679.953		188.218		1490.668	
Nagelkerke R2	0.168		0.189		0.165	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

With regard to the hypotheses, on can conclude that suppliers are used to process innovation activities (H3) and customers are used to product innovations (H4) (although support for the latter hypothesis is somewhat weaker). The importance of internal sources (H1) was confirmed in half of the equations (thereby in the most important – process and product innovations), so there are somewhat mixed results.

By trying to generalise the results otained in this section, one can present the importance of knowledge sources in a simplified scheme similar to the chain link innovation model described in section 1.1.1 (see Figure 11). As market finding activities were not included in the CIS questionnaire, this can be to some extent analysed by looking at the changes in internal knowledge management (measured via innovations in internal knowledge management) and external knowledge management (measured via relational innovations). These processes should show, whether the firm deals systematically with acquiring, selecting and maintaining new knowledge. As brought out by Faulkner (1995), new product ideas mainly emerge internally with some external inputs from other firms; in addition, the consultants may distribute the new product ideas across the industry. These process innovation indicators reflect only indirectly the search activities pursued by firms. Synthetic design, detailed design and testing activities are mainly related to industrial design activities, and product and service innovations. As this is the most deeply discussed type of innovation in the literature, many sources have been found to contribute to it (internal sources, customers, suppliers, competitors, universities etc.). Redesigning and producing activities are mesured by technological innovations, auxiliary process innovations and work organisational innovations.

By looking at the general pattern of knowledge flows in Figure 11 (the arrows show the relevance of knowledge sources according to types of innovations), it reflects the dominance of suppliers in innovation processes consistent with the taxonomy of Pavitt (1984). Suppliers are the source of knowledge contributing to each part of the innovation chain, but more intensively to production and design processes. The importance of customers (although similarly highly assessed) was found to concern only product innovations and design-related activities. Conferences are used for several stages – design production and distribution activities and competitors for design and distribution activities. Internal sources contribute more to core-activities such as designing, redesigning and producing. There are some country-specific factors (transitional education and science system) found to be relevant because the R&D institutes were not to contribute to any single stage, and universities were only to contribute to the work organisation.

Somewhat differently from the general literature is the finding that suppliers are only used for process innovation (not product) and customers are used for product (but not for process) innovation. This shows that firms can further enhance their innovative activities by expanding their knowledge exchange via business networks. Of course, the use of the knowledge stemming from customers can be intensified only if the firms move closer to the customers, because a lot of information is lost right now due to the use of distributors or traders, who have no capabilities or motivation for selecting and distributing the innovation related knowledge from the customers to the producers.

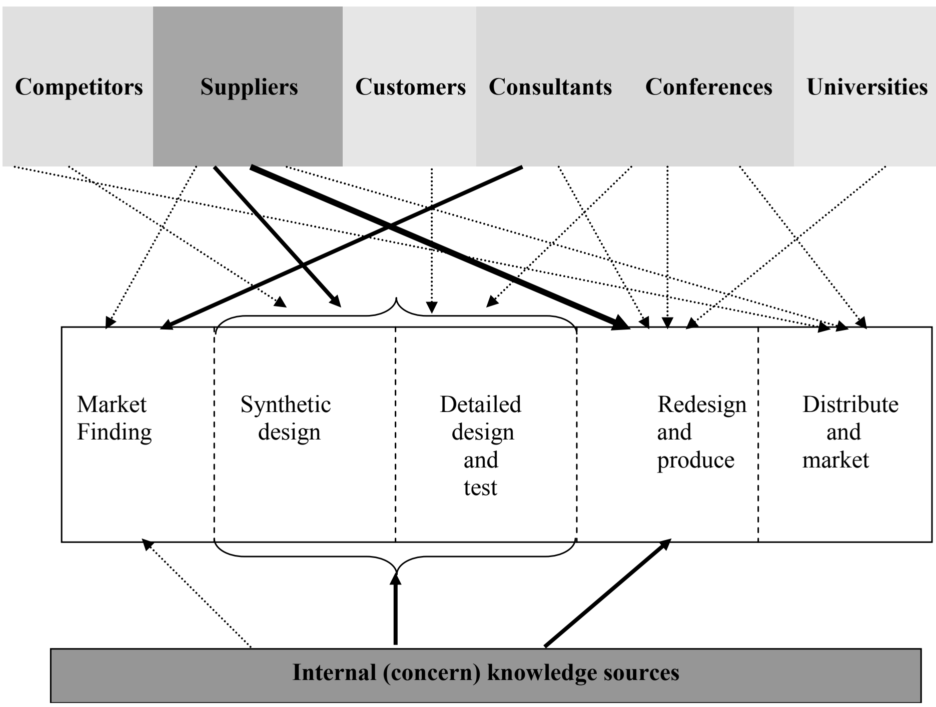

Figure 11. Chain-link innovation model for the Estonian wood sector

However, one can make several additional conclusions based on the results. At first, innovative activities mainly resulting from the use of internal knowledge sources or acquiring the knowledge from external sources rather than from pure expenditure on external knowledge acquisition (none of the expenditure coefficients was found to be significant). Secondly, the processes of innovation and underlying knowledge exchange processes are sector specific.

2.2.3. Factors determining the choice of innovation sources

Internal and external knowledge sources are needed in any company to suggest new innovation projects or contribute to the implementation of existing projects. In the following analysis company choices regarding innovation sources are analysed separately, enabling us to test hypotheses H2, H5, H6 and H7. The following innovation sources are analysed using separate equations: within the enterprise; in other enterprises within the concern; suppliers of equipment, materials, components or software; clients or customers; competitors and other firms in the same industry; consultants; universities and colleges and their units and institutes; public and private non-profit R&D institutions; professional conferences, meetings and journals; fairs exhibitions and industry associations.

In practice, not all these information sources were available to all companies, but since the availability of alternatives cannot be detected from the data, a simplifying assumption is made that all alternatives are available to all companies. Some companies also use several information sources simultaneously in different combinations, but again this is not studied here.

For each information source, a binary logit model is constructed in order to model the specific choice behaviour and explain it using a set of explanatory variables. The dependent variable in each model has two values: 1 – if the information source is chosen and 0 – if it is not chosen. The estimation procedure is identical to the one described in section 2.2.2. However, here it has to be noted that the factors were analysed using both databases CIS3 (1998–2000) and CIS4 (2002–2004). As the methodology has changed in several respects, not all variables can be used in a similar way (the inclusion of the respective variable is shown in brackets according to years). The following variables are entered in the models:

1) Attributes of companies:

Lnturnover: the logarithm of the annual turnover in 2000 and 2004;

Export: share of exports in turnover in 2000 and 2004;

Concern: binary variable (=1 if the company belonged to a concern in 2000 and 2004; and =0 if not);

Foreign: binary variable (=1 if foreign ownership was present and 0 if not);

Local market: binary variable (=1 if the firm marketed its products on the local or regional market in 2002–2004);

Domestic market: binary variable (=1 if the firm marketed its products on the domestic market in 2002–2004);

EU market: binary variable (=1 if the firm marketed its products on the EU market in 2002–2004);

2) Innovativeness of companies:

Costs: innovation costs as a share of turnover (2000 and 2004);

Machinery costs: costs for machinery, equipment and software as a share of turnover (2004);

External knowledge acquisition costs: costs of patents, non-patented inventions, skills, licences or other knowledge as a share of turnover (2004);

Training costs: costs of training (conducted both, internally and externally) oriented specifically towards product or process innovations as a share of turnover (2004);

Continuous R&D: (=1 if internal R&D activities were pursued continuously in 2002–2004);

Occasional R&D: (=1 if the internal R&D activities were pursued occasionally in 2002–2004);

Product innovation: binary variable (=1 if the firm implemented product innovation, which means a good or service which is either new or significantly improved with respect to its fundamental characteristics, technical specifications, incorporated software or other immaterial components, intended uses, or user-friendliness) in 1998–2000;

Own product innovation: (=1 if the firm was mainly responsible for product innovations applied in 2002–2004);

Cooperative product innovation: (=1 if the firm together with other cooperation partners was mainly responsible for product innovations applied in 2002–2004);

Concern product innovation: (=1 if the concern was mainly responsible for product innovations applied in 2002–2004);

Process innovation: binary variable (=1 if the firm implemented process innovation, which includes a new and significantly improved production technology, new and significantly improved methods of supplying services and of delivering products. The outcome should be significant with respect to the level of output, quality of products or costs of production and distribution) in 2000;

Own process innovation: (=1 if the firm was mainly responsible for process innovations applied in 2002–2004);

Cooperative process innovation: (=1 if the firm together with other cooperation partners was mainly responsible for process innovations applied in 2002–2004);

Concern process innovation: (=1 if the concern was mainly responsible for process innovations applied in 2002–2004);

Sales of new-to-firm products: the share of new-to-firm products in sales in 2004;

Sales from new-to-market products: the share of new-to-market products in sales in 2004;

Public support: (=1 if the firm received national public support for innovations in 2002–2004);

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

Knowledge related barriers:

B_technknow: lack of information about technology;

B_marketknow: lack of information about markets;

B_labour: lack of qualified personnel;

B_org: organisational rigidities;

B_partners: difficulties in finding partners for innovation (2002–2004);

Cost-related barriers:

B_cost: innovation costs are too high;

B_nofinance: lack of appropriate sources of finance (1998–2000);

B_internal finance: lack of finance within the firm or concern (2002–2004);

B_external finance: lack of external sources of finance (2002–2004);

Market related barriers:

B_risk: excessive perceived economic or demand-related risks;

B_dominant firms: the dominance of established firms on the market (2002–2004).

B_law: insufficient flexibility of regulations or standards;

Reasons not to innovate:

B_consumers: lack of customer responsiveness to new goods or services;

B_earlier innovations: no need for innovations because of earlier innovations;

4) Cooperation arrangements involving innovation activities with other enterprises or institutions. All these variables can take 4 values according to the importance of the cooperation activities for innovation (0 – not used, 1 – low importance, 2 – medium importance, 3 – high importance):

C_suppliers: suppliers of equipment, materials, components of software;

C_nonprofit_R&D: public and private non-profit R&D institutions;

C_competitors: competitors and other firms from the same industry;

C_concern: other enterprises within the concern (1998–2000);

C_consultants: consultants, enterprises offering R&D services;

C_consumers: clients or customers;

C_universities: universities and other higher educational institutions.

C_associations: industrial associations (2002–2004).

The results from estimating these models are in Table 26, and again show that the segmenting of the firms on the basis of industrial sectors is meaningful to explain most of the alternative choices of information source. The choices of innovation sources, where the null–hypothesis could not be rejected in CIS3 models, were suppliers, consumers and consultants, meaning that the analysed choice factors in those models are not different for the wood sector compared to other sectors in the economy. However, the CIS4 results show that the wood sector has some specificity concerning the choices of all knowledge sources compared to the overall economy.

Table 26. Log-likelihoods for the estimated binary choice models

LNg(βg) in models	All sectors	Wood sector	Other sectors	df
Results of the models for CIS3 data (1998–2000)				
Within the enterprise*	–467.7015	–33.259	–422.9475	6
Within the concern*	–473.1925	–34.4165	–424.177	8
Suppliers	–554.6735	–49.4055	–501.445	4
Customers	–524.377	–48.797	–472.2665	5
Competitors*	–618.0595	–49.1085	–553.966	8
Consultants	–535.087	–51.3415	–479.6175	5
Universities*	–500.8865	–27.8535	–461.8195	7
Non–profit R&D institutions*	–312.966	–18.4285	–285.0325	6
Conferences, meetings*	–682.581	–67.5625	–596.0445	5
Fairs, exhibitions*	–625.991	–52.483	–565.6705	5
Results of the models for CIS4 data (2002–2004)				
Within the enterprise or concern*	–531.668	–66.754	–445.73	15
Suppliers*	–636.583	–45.0995	–566.995	17
Customers*	–588.378	–52.054	–521.356	18
Competitors*	–724.386	–62.389	–647.307	12
Consultants*	–528.659	–35.6895	–470.205	19
Universities*	–414.861	–29.646	–374.502	10
Non–profit R&D institutions*	–434.115	–28.7315	–391.117	8
Conferences, fairs, exhibitions*	–661.453	–56.8265	–587.147	15
Industry associations*	–625.424	–42.3355	–554.933	15
Journals*	–712.485	–68.7985	–634.751	9

* Models where the null-hypothesis was rejected at 5% level

By interpreting the results of the models in this section, the models concerning the earlier period are discussed first on the basis of each knowledge source. As can be seen from Table 27, greater turnover is significant for the wood sector as well as other sectors in the economy. This result is generally expected, as smaller firms tend to have more limited financial and human resources, are less ready to access information and have shorter time horizons (OECD, 1999:51–52). In addition, they are generally considered to be more risk averse and reluctant to seek outside help, except for very specific short–term needs. In the furniture industry, the industry interviews also revealed the opinion that small firms do not acquire information concerning innovation, because they are not able to make use of it (Kull, 2003).

Table 27. Innovation sources within the enterprise 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Lnturn	0.130***	0.047	0.548**	0.241	0.115**	0.049
B_risk	0.091	0.087	1.274***	0.519	0.034	0.090
B_nofinance	0.026	0.077	–0.497*	0.269	0.069	0.093
B_personnell	0.269***	0.085	1.493****	0.448	0.201**	0.089
B_law	0.143	0.093	–0.983**	0.473	0.182*	0.098
ASC	–0.151	0.466	–3.974*	2.203	0.017	0.485
–2LL	935.403		66.518		845.895	
Nagelkerke R2	0.048		0.427		0.038	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The companies in the wood sector that claimed to lack qualified personnel for innovation, tended to choose internal innovation sources. At first sight this seems contradictory, because the use of internal innovation sources would generally presume having qualified personnel in the company. However, if we look at the composition of the labour force in the firms in CIS3 database[52], we see that companies in wood industries have relatively low shares of employees with higher and secondary professional education compared to other industries. The idea that a blue–collars education is not satisfactory in Estonia is supported by the interviews in different sub-sectors – furniture, wood-based panel, and window production. The lack of skills among employees (especially factory workers) is even stressed in an interview with one of the forest sector managers as the main impediment in technological upgrading. The main problems in terms of skills are a lack of modern ICT knowledge (computer skills and skills for working with electronics), international skills (knowledge of languages (very important in the case of fitters working abroad with clients, for example)), professional skills, but also motivation (Kull, 2003; Kukk, 2003; Agasild, 2003). This situation limits companies' absorptive capacities. They are not able to use the wide range of knowledge available from different sources, and rely mainly on innovation sources located within the enterprise. Consequently these firms are more inclined to incremental innovations.

[52] Unfortunately, this analysis was not possible to make on the basis of CIS 4 survey, because respective question was withdrawn from the questionnaire.

Table 28. Innovation source within the concern 1998–2000

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
Export	–0.094	0.232	3.721***	1.296	–0.276	0.253
Foreign	2.085***	0.173	1.953***	0.662	2.110***	0.184
Cost	0.012	0.023	0.688	0.521	–0.349	0.415
B_labour	0.133*	0.080	–0.016	0.306	0.122	0.085
B_nofinance	–0.353***	0.090	–0.956***	0.383	–0.301***	0.097
B_cost	0.344***	0.094	1.431***	0.414	0.279***	0.100
Local market	–0.818***	0.233	2.990***	1.394	–0.943***	0.239
ASC	–1.944***	0.204	–5.561***	1.305	–1.785***	0.212
–2LL	946.385		68.833		848.354	
Nagelkerke R2	0.316		0.592		0.314	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Companies with a strong export orientation and foreign ownership chose members of the concern as sources of innovation. Here it has to be noted that this alternative was probably available only to concern members and most of them (over 70% in CIS 3 sample) belonged to a foreign concern. The rest comprises domestically owned concerns that could be more oriented towards local markets and exchange knowledge even more. The analysis here remains insubstantial for clarifying this result, but a dichotomy between foreign owned and domestic concerns would not be surprising. However, the results show that the knowledge accumulation process has taken place at concern level and is not disseminated to other companies in the sector (however, one can say already here that by looking at the estimation results in Table 35, this situation changed some years later).

From Table 29, we find evidence that firms belonging to a concern, which possibly has been operating on the market for a long time, can rely at least to some extent on knowledge transfer within the concern in their innovation processes. Indeed, the cooperation for innovation within the concern was considered very important in several interviews [1, 3, and 6]. As a negative aspect, such firms revealed that the mother company determines the speed and direction of development in the Estonian subsidiary. Since certain types of training costs for employees are taxed in Estonia (because they are treated as special bonus to employees), the firms train their staff less than desired (this appeared to be stressed more in foreign affiliates and therefore could be considered a hindrance to knowledge spillovers) [3].

Table 29. Innovation sources within the enterprise or concern 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	Bi	S.e.	βi	S.e.	βi	S.e.
Concern	1.461***	0.176	2.042***	0.561	1.533***	0.196
Own product innovation	1.055***	0.203	2.321***	0.634	1.025***	0.226
Own process innovation	0.256	0.217	0.861	0.597	0.160	0.243
Cooperative process innovation	0.433	0.287	2.309***	0.842	0.290	0.320
Sales from new to market products	2.517***	0.856	0.423	2.897	2.431***	0.911
Continuous R&D	1.349***	0.251	1.262*	0.716	1.371***	0.277
Occasional R&D	1.244***	0.319	0.629	0.820	1.534***	0.374
Machinery costs	2.914***	0.193	2.491***	0.629	3.076***	0.213
B_risk	0.133	0.088	0.693**	0.288	0.057	0.096
B_costs	0.022	0.079	–0.863***	0.254	0.144*	0.087
B_techknolwedge	0.300***	0.108	0.767**	0.338	0.286**	0.118
B_partners	–0.133	0.104	–0.546*	0.303	–0.111	0.115
C_consultants	0.766	0.487	–2.959**	1.283	1.122**	0.557
C_suppliers	1.147***	0.304	1.764**	0.831	1.156***	0.353
ASC	–3.566	0.194	–4.044***	0.688	–3.671***	0.214
–2LL	1063.335		133.508		891.460	
Nagelkerke R^2	0.709		0.693		0.727	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

By analysing the hypotheses constructed, we can see that firms with continuous R&D activities rely more on internal knowledge sources when innovating, but training costs do not seem to be relevant. Stronger internal knowledge sources also encourage cooperative innovations with external partners, besides innovation worked out internally. In addition, the internal sources were used by the firms selling on the local market (the problem of reorientation from exports to the domestic market was discussed in section 2.1.2). Internal sources were used by firms with large investments in machinery and by firms who claimed to lack technological knowledge for implementing the purchased technology (therefore, supplier-cooperation was also used). Interestingly, internal sources were also used less by firms claiming difficulties in finding innovation partners, and by firms using consultants (of course, if internal sources are sufficient, no consultants are needed).

Evidence can be found from Tables 27–29 to suggest that financing barriers are associated with the lower probability of using internal (and concern) knowledge sources for innovation. Knowledge-related barriers enhanse the use of such sources (except in firms with difficulties finding cooperation partners).

According to the classification by Pavitt (1984), wood sector firms are characterized by supplier-dominated innovation processes. This has also been generally confirmed by the interviewed managers – suppliers are considered to be very important; however, in addition to the suppliers of machinery and equipment stressed by Pavitt, the suppliers of all kinds of complementary materials and semi-finished products that transfer their knowledge to help solve problems concerning products or processes were also brought out [9, 15]. Often those complementary products or materials are supplied by the distributors in Estonia, but sometimes the lots are bought from larger distributors of producers in Europe (for example, when a greater quantity or variety is needed or the material or product is so novel that it has not reached Estonian distributors) [9].

Table 30. Suppliers as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	Bi	S.e.	βi	S.e.	βi	S.e.
Procinno	1.041***	0.110	1.275***	0.157	1.039***	0.157
B_org	0.304***	0.107	1.384***	0.553	0.225**	0.113
B_techknow	0.465***	0.090	0.632**	0.269	0.446***	0.103
ASC	–0.157	0.133	–0.626	0.515	–0.132	0.138
–2LL	1109.347		98.811		1002.890	
Nagelkerke R2	0.143		0.276		0.136	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

As can be seen from Table 30, suppliers are mostly used as innovation sources by firms with process innovations who claim to lack sufficient technological knowledge for innovation. The suppliers of machinery and equipment are as a rule large firms operating around the world, thereby making the modern technology available everywhere; however, each specific item is to some extent adjusted to the customer needs [4, 7]. Often, the Estonian subsidiaries of those large firms are small, incompetent and still learning basic things from their customers, who use this modern technology [1, 14]. The firms react to this weakness of suppliers in different ways – some facilitate such learning processes, but others are rather reluctant, because they expect the knowledge transfer to be the other way around and in fact they have already paid for knowledge they never received by purchasing the technology [9,14]. There are also some smaller local technology producers and distributors, who are considered to be relevant innovation partners [2], but cooperation with such partners is only occasional and occurrs when some problems arise with technology etc. [3]. Here, the conclusion can be made that local supporting industries have not developed enough to strengthen such relationships.

By looking at Table 31, one can see that suppliers are used in firms with large investments in machinery and firms with different process innovations, and in this the firms try to diminish the lack of technological knowledge as a barrier. Suppliers are also used less by firms claiming to have no partners for innovation. In addition, suppliers are used more by members of the concern and by firms with both, novel and incremental product innovations. The firms, whose customers were not innovation demanding, used suppliers less as knowledge sources. From Tables 30 and 31, one can find supporting evidence for H2, H6 and H7, because stronger internal capabilities (measured on the basis of occasional and continuous R&D activities) enhanced the use of suppliers as did knowledge-related barriers to innovation. The financing barriers had expected signs, except for external financing barriers, which decreased the probability of using suppliers as knowledge sources.

Table 31. Suppliers as innovation sources 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
Concern	0.657***	0.151	2.526***	0.769	0.563***	0.160
Own product innovation	0.719***	0.196	2.315***	0.801	0.497**	0.211
Cooperative product innovation	0.980***	0.283	2.324**	0.962	0.766***	0.305
Own process innovation	1.411***	0.183	2.629***	0.776	1.382***	0.196
Cooperative process innovation	2.427***	0.296	3.320***	1.281	2.487***	0.310
Sales from new to market products	–0.549	0.674	14.787*	7.934	–0.490	0.697
Sales from new to firm products	1.140***	0.356	3.154**	1.461	1.098***	0.375
Continuous R&D	1.185***	0.219	1.899*	0.995	1.247***	0.230
Occasional R&D	0.432*	0.263	2.703**	1.212	0.400	0.279
Machinery costs	17.360***	2.954	30.063***	10.588	15.507***	3.115
B_customers	–0.287***	0.077	–0.664*	0.369	–0.271***	0.080
B_external finance	0.067	0.075	1.001***	0.350	0.030	0.080
B_costs	0.133*	0.076	–0.792**	0.352	0.171**	0.080
B_partners	-0.011	0.088	–0.725*	0.416	0.022	0.093
B_risk	0.192**	0.082	0.988**	0.422	0.178**	0.087
C_suppliers	2.315***	0.288	20.141	6009.529	2.279***	0.293
ASC	–2.484***	0.156	–4.314***	0.880	–2.445***	0.164
–2LL	1273.165		90.199		1133.989	
Nagelkerke R^2	0.614		0.825		0.599	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Customers as knowledge sources are used more by firms with (novel, but also incremental) product innovations, and by companies with insufficient market knowledge for innovation (see Tables 32, 33), but also by firms lacking technological knowledge. In addition, from Table 32, we can see that customers are also used for some types of process innovations. Customers are more likely to be used by exporting firms, but also by firms selling on the domestic market. Firms that claim they do not have innovation-demanding customers use such customers as knowledge sources less. It is evident from the estimated models that customers are used to acquire knowledge more by concern members and less by firms who receive public support for innovation, but also more intensively by firms who claim that the dominance of established firms on the market is a barrier to innovation. The interview results revealed that this source is most important for gaining market knowledge and therefore the firms would like to be as close as they possibly can to their end-user.

From Tables 32–33, we can also find supporting evidence for H2 and H7; however, concerning H6, the external barriers seem to encourage the use of customers as knowledge sources.

Table 32. Customers as innovation sources 1998–2000

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	Bi	S.e.	βi	S.e.	βi	S.e.
Prodinno	0.966***	0.166	1.462**	0.533	0.940***	0.177
B_nofinance	–0.041	0.064	–0.500**	0.222	0.005	0.068
B_org	0.485***	0.115	0.761*	0.437	0.473***	0.120
B_marketknow	0.406***	0.095	0.721**	0.300	0.367***	0.101
ASC	–0.038	0.173	0.159	0.553	–0.061	0.183
–2LL	1048.754		97.594		944.533	
Nagelkerke R2	0.140		0.289		0.131	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The role of competitors as a source of innovation is rather different in the wood sector compared to other sectors. In the wood sector, information from competitors is relevant for more export-oriented companies and companies that do not belong to the concern (CIS3 results).

This fact can be partially clarified by reviewing the interviews according to which domestic companies are not real competitors (as exceptions, sawmills can be considered, because they are competing domestically and are also to a great extent members of concerns). Other sub sectors mainly export and do not sell much on the domestic market. Very often companies collaborate in order to strengthen their competitiveness on foreign markets (Kull 2003, Kuldkepp

2003, Agasild 2003). The results of the earlier innovation survey indicate that concerns have been quite closed units not cooperating with domestic firms in the same industry (see Table 34); however, as can be seen from Tables 35 and 36, this situation has changed – competitors and industry associations are used by firms with formal concern cooperation (therefore, one cannot accept H5 in the later period).

Competitors are used more by exporting firms in the earlier period, but this was not evident in the later survey, where the orientation towards the local market increased. The competitors were assumed not to perform formal cooperation activities, but rather informal, which was rejected by the data; however, formal cooperation between competitors has led to stronger cooperation in industry associations.

Table 33. Customers as innovation sources 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Concern	0.614***	0.158	1.071*	0.594	0.590***	0.168
Export	0.222	0.206	1.490*	0.848	0.147	0.224
Domestic market	0.488***	0.173	1.261*	0.699	0.454***	0.183
Own product innovation	1.556***	0.208	2.281***	0.739	1.485***	0.225
Own process innovation	1.259***	0.201	3.126***	0.759	1.144***	0.217
Cooperative process innovation	1.719***	0.268	3.413***	0.933	1.666***	0.287
Sales from new to market products	0.893	0.822	16.662*	9.205	0.730	0.823
Sales from new to firm products	3.469***	0.468	3.602***	1.388	3.646***	0.519
Continuous R&D	1.628***	0.252	3.476***	1.196	1.537***	0.263
Occasional R&D	1.046***	0.282	2.703**	1.216	0.962***	0.298
Public support (national)	–0.525	0.389	–3.270***	1.291	–0.403	0.431
B_external finance	0.033	0.070	0.557**	0.245	0.004	0.077
B_techknolwedge	0.289***	0.091	0.712**	0.350	0.264***	0.097
B_no demand	–0.241***	0.078	–0.685**	0.337	–0.217***	0.081
B_dominant firms	0.026	0.080	–0.558*	0.301	0.077	0.085
B_risk	0.141	0.088	0.870***	0.356	0.105	0.093
C_customers	2.891***	0.364	2.233	1.398	2.923***	0.382
ASC	–2.916***	0.219	–6.104***	1.212	–2.801***	0.227
–2LL	1176.756		104.108		1042.712	
Nagelkerke R^2	0.662		0.783		0.657	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Cooperation on specific innovation activities is very weak between companies as assessed by several interviewees. For some firms this could be explained by the small scope of the market, because cooperative projects assume something larger that involve large markets in order to pay. In addition, since many of the firms are niche producers, they have very diverse interests. However, this type of cooperation was recognised as strong in some sub-sectors, perhaps the strongest in the forest industry concerns having subsidiaries in sawmilling and planing. Some firms indicated activities that could be identified as "co-opetition" and is considered as an advanced level of cluster relationship according to Formica's (2002) model [5,16,17]. This cooperation can best be illustrated by the words of one manager: "*Swedish forest concerns cooperate in Estonia within this cocktail mixed by /Estonian firms/ for instance in logistics and management of trade flows /.../, from time-to time in correcting the prices or starting something together to make it more active. But they would never do this kind of cooperation in Sweden – their trucks would never transport other firm's logs. This is rare, but this is imported to other Baltic countries via subsidiaries of Estonian concerns.*"

Table 34. Competitors as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	Bi	S.e.	Bi	S.e.
Export	–0.286	0.198	2.243***	0.767	–0.619***	0.206
B_risk	0.278***	0.071	0.557*	0.332	0.274***	0.074
B_org	0.492***	0.096	1.008**	0.429	0.483***	0.100
B_consumer	–0.054	0.073	–0.461*	0.275	–0.051	0.077
C_suppliers	–0.218***	0.073	–0.599*	0.337	–0.205***	0.076
C_concern	0.002	0.095	–1.074***	0.402	0.085	0.101
C_competitors	0.844***	0.153	2.932**	1.347	0.775***	0.153
ASC	0.205*	0.123	–0.189	0.476	0.218**	0.129
–2LL	1236.119		98.271		1107.932	
Nagelkerke R2	0.139		0.361		0.147	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

It was mentioned in some cases, that managers often fail to see the world more broadly, and the position of the firm in the sector is seen too narrowly (only in the Estonian market, or even more narrowly, only in a specific location), and therefore they cannot see the wider opportunities and gains from cooperation [8,14].

Table 35. Competitors as innovation sources 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	Bi	S.e.	βi	S.e.
Local market	0.081	0.138	–0.993*	0.537	0.125	0.146
Own product innovation	2.528***	0.150	3.630***	0.560	2.453***	0.159
Own process innovation	1.737***	0.289	3.334**	1.464	1.687***	0.298
Concern product innovation	2.394***	0.230	2.608***	0.731	2.413***	0.248
Cooperative process innovation	1.103***	0.232	2.693***	0.943	0.988***	0.245
Machinery costs	3.378***	1.058	20.252***	6.304	2.342***	0.905
B_earlier innovations	–0.300***	0.073	–0.769**	0.314	–0.252***	0.075
B_personnell	0.394***	0.063	0.579**	0.242	0.394***	0.066
B_dominant firms	0.049	0.069	–0.512**	0.264	0.092	0.073
B_risk	0.160**	0.074	0.762***	0.304	0.128*	0.078
C_concern	1.291***	0.239	1.959**	1.067	1.287***	0.246
ASC	–2.554***	0.168	–2.920***	0.644	–2.571***	0.177
–2LL	1448.772		124.778		1294.614	
Nagelkerke R^2	0.503		0.704		0.487	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The intensity of cooperation between firms is rather different across sub-sectors. In the furniture industry, for example, quite strong links exist on the basis of contracting some of activities out and the basis of these linkages is formed mainly from the mutual complementarities of the firms [1, 8]. Some cooperation in exchanging production capacities has also been revealed between woodworking and furniture firms [3]. Since most of the latest technologies are too expensive and too large in terms of production volumes for SMEs, these firms seek out cooperation with others that possess some of the needed technologies, and in addition, some joint procurement activities were also identified [3]. With regard to contract works, the client firm that is usually larger also offers the contractor SME training, because it is dependent on the quality of the semi-finished products (despite the fact that this activity might create a new competitor on the market) [11]. However, a change in market demand and respective innovations in products can also break off the existing cooperation linkages, because the contractor SMEs are not able to upgrade their technologies as quickly as needed. In Estonia, the larger firms do not help SMEs upgrade, which is different for example in Italian furniture clusters. Therefore, this could also be the place for public support for SMEs in advancing the cluster. It has to be stressed however, that the above-described adjustment per se may not be relevant, but rather the appropriate speed of adjustment [8].

Table 36. Industry associations as innovation sources 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Domestic market	0.582***	0.185	–1.755**	0.886	0.700***	0.198
Concern product innovation	1.014***	0.291	2.690*	1.479	1.027***	0.302
Cooperative product innovation	0.758***	0.212	3.224***	0.919	0.583***	0.232
Intramural innovation costs	0.953	1.087	–98.262*	51.424	1.177	1.087
Public support (national)	1.196***	0.260	3.956***	1.110	1.026***	0.291
B_internal finance	–0.028	0.084	–1.983***	0.542	0.072	0.087
B_earlier innovations	–0.246***	0.081	–2.135***	0.590	–0.185**	0.083
B_external finance	0.120	0.081	2.051***	0.551	0.034	0.086
B_personnell	0.210***	0.075	0.886***	0.351	0.168**	0.079
B_marketknow	0.076	0.096	0.952**	0.423	0.039	0.102
B_partners	0.008	0.092	–0.680*	0.401	0.083	0.097
B_risk	0.144*	0.082	0.626*	0.351	0.135	0.087
C_competitors	1.249***	0.204	3.650***	1.255	1.254***	0.215
C_concern	0.784***	0.226	4.401***	1.295	0.746***	0.237
ASC	–3.068***	0.209	–2.951***	0.900	–3.184***	0.224
–2LL	1250.847		84.671		1109.866	
Nagelkerke R^2	0.242		0.624		0.236	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

The importance of regional cooperation networks has not been mentioned by any of the firms – cooperation is rather on a national scale. The role of industry associations was assessed very differently. In certain smaller sub-industries, the associations are not present and the managers are sceptical about whether a larger association for broader industry groups would represent their interests. The largest industry associations are the Estonian Forest Industry Association (EFIA) comprising approximately 56 firms with a total number of employees of 5299, and the Estonian Woodworking Federation with 28 firms and 2800 employees. The former brings together forest and woodworking industries, but also pulp and paper industry firms and covers approximately 16.5% of those industries; the latter mainly represents furniture firms and covers 21.7% of this industry[53]. Among the firms interviewed, one woodworking firm belonged to both associations at the same time. The smaller associations include the

[53] The estimates are based on the share of employees in member companies from employment in the whole industry. The Statistical Office of Estonia and the industry associations were used as data sources (www.stat.ee, www.emtl.ee, www.furnitureindustry.ee).

Estonian Wooden Houses Association, the Union of Estonian Window and Door Manufacturers and so on, but regarding these the managers have very different opinions. The firms felt that the smaller associations are good for meeting and communicating with other managers; however, the smaller groups remain weak when it comes to representing the members at state institutions, such associations are too expensive to maintain for such a small number of firms. Despite that, the members of the smaller associations have been involved in more innovation-related cooperation (for example, in exchanging knowledge in the process of introducing CNC-technologies in firms) [2].

The firms see potential in the future to further improve the cooperation between SMEs in solving problems with raw materials (in some cases this kind of cooperation already exists) [2,7]. Regarding marketing cooperation, the firms do not see any relevant opportunities because they are too small on the world market and each of them has their own niche (for example, in one case production for the whole year in one sub-industry would be the size of a test-lot for the market), and orientating the whole industry to one market would be too risky for the whole sector. At the same time, there are firms in the sample who are selling their complementary products jointly [7, 15].

By taking the results from Tables 34–36 together, we find strong evidence in support of H7. The indicators of stronger internal capabilities were not significant in the case of competitor collaboration, and in the case of financing barriers the dichotomy between internal and external financing barriers was revealed again.

Table 37. Consulting firms as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Prodinno	0.317*	0.188	1.043**	0.627	0.259	0.200
Procinno	0.778***	0.183	1.211*	0.626	0.749***	0.192
B_cost	0.215***	0.067	0.639***	0.239	0.178***	0.071
C_consult	1.908***	0.207	0.897*	0.499	2.011***	0.228
ASC	–2.295***	0.263	–3.629***	1.803	–2.151***	0.274
–2LL	1070.174		102.683		959.235	
Nagelkerke R2	0.28		0.232		0.291	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Throughout the economy, consulting firms are used in product and process inno–vations by those firms that find innovation too costly. In these cases, knowledge transfer occurs under formal contracts. There is no great difference from other sectors in using this particular source of innovation (Table 38).

Table 38. Consulting firms as innovation sources 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
Export	–0.360	0.259	2.988***	1.210	–0.614**	0.286
Local market	0.181	0.171	–1.578**	0.768	0.291	0.183
EU market	0.421**	0.211	–3.263**	1.660	0.549***	0.217
Own product innovation	1.137***	0.213	2.354**	0.981	1.112***	0.229
Concern product innovation	1.154***	0.364	6.062***	2.021	1.029***	0.383
Cooperative product innovation	1.050***	0.276	3.044***	1.032	0.901***	0.302
Concern process innovation	0.799**	0.355	–5.873*	3.185	0.933***	0.365
Sales from new to market products	–0.715	0.646	–8.981*	4.807	–0.447	0.691
Continuous R&D	1.534***	0.203	3.420***	0.867	1.411***	0.220
Occasional R&D	1.292***	0.258	3.287***	1.156	1.235***	0.277
B_internal finance	0.071	0.090	–0.918**	0.454	0.117	0.093
B_earlier innovations	–0.024	0.088	–0.773	0.487	0.003	0.093
B_external finance	0.121	0.087	1.192***	0.419	0.070	0.092
B_risk	0.173**	0.082	0.651*	0.381	0.159**	0.087
C_consultants	3.007***	0.358	4.617**	2.171	3.040***	0.370
C_competitors	–0.227	0.313	–5.687***	2.061	–0.201	0.324
C_customers	–0.356	0.322	3.275**	1.657	–0.378	0.339
C_suppliers	0.723***	0.290	2.711**	1.350	0.726**	0.307
ASC	–3.755***	0.261	–3.187**	1.425	–3.789***	0.273
–2LL	1057.317		71.379		940.410	
Nagelkerke R^2	0.453		0.693		0.454	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Concerning the hypotheses constructed, one can see that the firms with internal financing barriers use consultants less (Table 38), but firms that claim they have external finance barriers do use more consultants. When only loans are meant as external financing, it seems reasonable that this type of financing is used for aquiring technology, but not for consulting services. When firms also consider public support for access to consultancy services, than this kind of support is available via Enterprise Estonia.

In addition to the above-described results, consulting firms seem to contribute to cooperative product and process innovation projects, but on the basis of firms earning less from selling novel products (but apparently on the domestic market). R&D activities enhance the use of consultants because the firms are more capable of benefiting from consulting services (in fact, one manager admitted there was a lack of skills in using consultants as a knowledge source in the Estonian economy generally – not only in the private, but also in the public sector [8]). Other cooperative arrangements with business partners also seem to contribute to the use of consulting firms as knowledge sources. Concerning hypohesis H2, strong evidence was found in Table 38, but interestingly, none of the variables inserted for testing H7 was found to be significant.

Table 39. Universities as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Foreign	–0.046	0.182	1.566**	0.759	–0.163	0.191
Procinno	0.456***	0.184	7.886	26.316	0.379**	0.188
B_risk	0.423***	0.072	0.817**	0.387	0.395***	0.074
C_suppliers	0.068	0.092	0.911**	0.451	0.019	0.094
C_customers	0.071	0.092	–0.681	0.495	0.103	0.093
C_concern	0.187**	0.090	–0.366	0.444	0.232***	0.093
ASC	–2.368***	0.195	–11.403	26.323	–2.190***	0.198
–2LL	1001.773		55.707		923.639	
Nagelkerke R2	0.097		0.387		0.092	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Universities have low importance in creating knowledge for innovations in wood sector companies. This fact was already revealed in the previous sections of this research. This source of innovation is more intensively used by foreign owned companies and by those who find risks as a barrier to innovation and also companies who cooperate with suppliers (see also Table 39).

It is evident from Table 40 that there is no indication that universities are used for developing novel products. At the same time we notice that the existence of formal cooperation agreements is also not relevant. Besides these results, some evidence is found that foreign-owned firms or concern members are using this kind of knowledge source less – that could indicate the FDI being more cost-advantage seeking than knowledge-based. It is also evident that universities are used by firms that have cooperative innovation arrangements with suppliers and less by firms that claim it is difficult to find innovation partners. The firms are trying to lower risks by acquiring additional market knowledge from universities.

Table 40. Universities as innovation sources 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
Continuous R&D	1.020***	0.221	1.703**	0.882	0.965***	0.235
Occasional R&D	0.611**	0.297	2.202*	1.231	0.480	0.319
External knowledge acquisition	1.014***	0.199	1.675**	0.828	0.940***	0.210
Training costs	1.130***	0.235	2.796***	1.055	1.048***	0.248
B_external financing	0.216***	0.080	0.958***	0.333	0.173**	0.085
B_personnell	0.104	0.094	–0.342	0.424	0.138	0.097
B_marketknolwedge	0.033	0.112	1.123***	0.449	–0.054	0.119
B_partners	0.112	0.109	–0.901*	0.497	0.190*	0.114
C_suppliers	1.410***	0.195	1.800**	0.817	1.489***	0.209
ASC	–4.326***	0.234	–7.621***	1.537	–4.187***	0.238
–2LL	829.722		59.292		749.003	
Nagelkerke R^2	0.411		0.612		0.406	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Table 41. Journals as innovation sources 2002–2004

Independent Variables	All Sectors		Wood Sector		Other Sectors	
	βi	S.e.	βi	S.e.	βi	S.e.
Lnempl	0..260***	0.065	0.523**	0.239	0.250***	0.069
Continuous R&D	2.484***	0.171	2.380***	0.572	2.479***	0.181
Occasional R&D	2.136***	0.225	3.421***	0.814	2.019***	0.237
B_earlier innovations	–0.321***	0.071	–0.835***	0.288	–0.271***	0.074
B_costs	0.159***	0.062	0.321*	0.195	0.133**	0.067
B_techknow	0.363***	0.086	0.982***	0.309	0.310***	0.091
B_partners	0.061	0.082	–0.556**	0.285	0.129	0.087
C_suppliers	1.570***	0.194	2.254***	0.590	1.516***	0.208
ASC	–3.024***	0.273	–4.539***	1.084	–2.951***	0.286
–2LL	1424.970		137.597		1269.501	
Nagelkerke R^2	0.479		0.611		0.471	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

One method of using the knowledge created by research activities is also through published results. This is also one way of using foreign research results and it seems that Estonian wood sector firms do use this source especially to gather technological knowledge. In addition, this source is used by firms that find innovation activities too costly. It can be seen from Table 41, that this seems to substitute partnerships and is less used by firms who don't have the pressure to innovate because of earlier innovations.

Table 42. Innovation sources in non-profit R&D institutions 1998–2000

Independent	Full model		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Prodinno	–0.673***	0.247	–3.170***	1.229	–0.585**	0.262
B_marketknow	0.455***	0.115	1.601***	0.592	0.404***	0.121
B_nofinance	0.063	0.095	–1.335**	0.559	0.150	0.100
C_nonprofit_R&D	2.234***	0.266	2.959**	1.420	2.262***	0.289
Local market	0.266	0.243	3.498***	1.381	0.104	0.254
ASC	–2.522***	0.275	–2.012**	0.885	–2.583***	0.295
–2LL	625.912		36.257		570.065	
Nagelkerke R2	0.243		0.490		0.250	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Since public and private non-profit R&D institutions are almost non-existent in the Estonian wood-processing field, companies use such sources outside of Estonia. The fact that foreign institutes in Finland and Great Britain are used as a source of innovations is supported by the industry interviews of earlier periods (Botvinkina, 2003).

Table 43. Non-profit R&D institutions as innovation sources 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Concern	0.287	0.215	–2.320**	1.043	0.424**	0.227
Occasional R&D	0.324	0.272	3.326***	1.144	0.075	0.296
Training costs	1.942***	0.214	4.374***	1.182	1.894***	0.225
B_external finance	0.249***	0.080	0.746**	0.328	0.241***	0.085
B_marketknolwedge	0.124	0.108	1.478***	0.497	0.030	0.117
B_partners	0.109	0.105	–1.509***	0.574	0.191**	0.109
C_concern	0.783***	0.253	3.712***	1.456	0.679***	0.263
ASC	–4.097***	0.228	–7.053***	1.420	–4.027***	0.237
–2LL	868.229		57.463		782.233	
Nagelkerke R^2	0.238		0.535		0.235	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

However, it is interesting to note that in 2002–2004, the concern members generally didn't use R&D institutes as knowledge sources, but those having formal innovation cooperation agreements within a concern used this kind of knowledge source relatively more often. A lack of funds decreases the likelihood of choosing R&D institutions as a source of innovations. Those companies that claimed to have too little market knowledge, have a greater likelihood of choosing information from R&D institutions.

From the results, we can see that in the earlier period, the existence of formal cooperation arrangements played a role in knowledge exchange, but not any more. Similarly, the finance barriers in firms who use this kind of source have vanished. It seems (see Table 43) that R&D institutes are also used in cases where other partners are not available.

Table 44. Conferences as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Lnturn	0.122***	0.039	0.507***	0.175	0.160***	0.042
Foreign	–0.216***	0.460	–1.032**	0.513	0.209	0.156
Costs	0.202	0.168	0.059	0.072	2.615***	0.631
B_risk	0.369***	0.061	0.601***	0.228	0.332***	0.065
ASC	–1.085***	0.364	–5.057**	1.616	–1.505***	0.407
–2LL	1365.162		135.125		1192.089	
Nagelkerke R2	0.067		0.219		0.091	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Larger companies use conferences and meetings more often to obtain information, but companies with foreign ownership use this source less than those of domestic ownership (see Table 45). Here the complementarities of different information sources could also be seen: foreign-owned companies rely more heavily on information within their concern and use less information from outside sources.

Fairs and exhibitions are also used by larger companies and by companies with labour barriers to innovation. To encourage this particular innovation source, government financial support has been extended for many years, and hence this source is also available to firms with a low level of finances for innovation.

By looking at the later period, one can see that many factors have remained the same (size, risk barrier, personnel barrier). Conferences are used by firms for product and process innovation, but it seems that since cooperation with suppliers and investments in machinery are significant, process innovators might use competitors relatively more often. In this way, firms that use less consulting firms, use conferences and fairs relatively more – probably indicating some similarity in knowledge obtained from both sources (especially if we recall that consultants were used to acquire market knowledge). Firms that do not feel the need to innovate because of earlier innovations use conferences less, but firms who are constrained by a dominant player on the market also find conferences and fairs an irrelevant source of knowledge.

Table 45. Fairs as innovation sources 1998–2000

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Lnturn	0.188***	0.038	0.713***	0.202	0.160***	0.039
B_cost	0.360***	0.063	0.397*	0.239	0.356***	0.066
B_personnell	0.269***	0.068	0.699***	0.273	0.251***	0.071
B_law	0.072	0.073	–0.608*	0.318	0.116	0.075
ASC	–1.947***	0.379	–6.504***	1.895	–1.729***	0.392
–2LL	1251.982		104.966		1131.341	
Nagelkerke R2	0.123		0.327		0.116	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

Table 46. Conferences and fairs as innovation sources 2002–2004

Independent	All Sectors		Wood Sector		Other Sectors	
Variables	βi	S.e.	βi	S.e.	βi	S.e.
Lnempl	0.294***	0.072	0.697***	0.265	0.249***	0.077
EU market	0.468***	0.162	3.011***	1.079	0.406***	0.165
Own product innovation	2.107***	0.167	2.901***	0.602	2.103***	0.179
Concern product innovation	2.086***	0.303	2.327*	1.319	2.126***	0.311
Cooperative product innovation	1.804***	0.246	1.983**	0.896	1.801***	0.261
Own process innovation	1.284***	0.174	2.188***	0.619	1.196***	0.187
Cooperative process innovation	1.782***	0.261	2.982***	1.060	1.753***	0.275
Machinery costs	5.533***	1.580	18.392***	7.365	4.035***	1.610
B_earlier innovations	–0.306***	0.076	–0.623**	0.287	–0.276***	0.080
B_personnell	0.325***	0.066	0.482*	0.273	0.334***	0.069
B_dominant firms	0.015	0.074	–0.973***	0.302	0.087	0.078
B_risk	0.209***	0.078	0.711**	0.307	0.175**	0.082
C_consultants	0.329	0.361	–3.113*	1.686	0.491	0.372
C_suppliers	1.212***	0.237	3.540***	1.276	1.113***	0.247
ASC	–3.893***	0.317	–8.137***	1.694	–3.724***	0.330
–2LL	1322.906		113.653		1174.293	
Nagelkerke R^2	0.589		0.761		0.577	

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

In conclusion, the larger the company the greater the likelihood of choosing several analysed innovation sources (internal resources, but also conferences, fairs and journals); however, in other sources this was not confirmed. The firms with stronger internal capabilities (R&D activities, but also training) seem to use more internal knowledge, but also more external sources (except for competitors, industrial associations and conferences, where this was not found to be significant). Since the main sources (internal, suppliers and customers) showed confirming results, one cannot reject hypothesis H2. Organisational and personnel barriers seemed to play a role in most knowledge sources (except for consultants and R&D institutes, which are minor sources); therefore, one can also not reject H7.

Regarding external business sources, risk aversion forces companies to seek information from several sources, and as an essential barrier for wood sector firms, a lack of finances for innovating can be considered. This factor diminishes the likelihood of using several information sources (supporting H6) in case internal financing barriers are considered. However, the presence of external financing barriers seems to increase the likelihood of using several external knowledge sources. It may well be (as judged also by the interviews) that both barriers are related and show only different strengths of financing barriers. The firms with severe internal barriers do not receive external funding because of the existence of critical financial reports (in the form of loans or in the form of public support), they deal less with knowledge exchange and more with survival. Firms with sufficient internal resources would seek more external funding for development.

From the other factors behind the choice of knowledge sources analysed, there are many in line with earlier empirical research; however, some sectoral specificities can also been seen. Internal sources are more relevant for innovation in larger firms and in firms with some internal R&D activities; R&D activities also enhance firms so they can use external knowledge sources (absorptive capacity argument). Suppliers and customers are used respectively for process and product innovations and by firms lacking technological or market knowledge. These patterns are quite clear in the wood sector, and this is different from the evidence in literature showing customer contribution to process innovations in some other sectors. Suppliers contribute to product innovations in wood sector firms as well because product innovations are often drawn from innovations in technological processes.

Competitors and industry associations are used for several types of cooperative innovation projects and concern member firms are becoming more and more embedded in local networks (no support for H5 in the latter period). Consulting firms are used besides consumers for receiving market-related information, but here formal cooperation is causing the firms to recognise the financial barriers.

However, the export orientation of firms did not play as relevant a role as expected in the later period (because of the close connection between wood sector firms and the construction sector booming internally and the respective reorientation of the firms to the domestic market). Formal innovation cooperation agreements didn't encourage the use of knowledge sources (except for consultants). Concerning public knowledge sources (universities and R&D institutions), R&D spending encouraged the use of universities, and a similar effect is shown by expenditures on innovation-related training by universities and R&D institutes. The fact that both public sources are used for market rather than technological knowledge could be expected (although it is contrasting the literature), because of the weakness of public technology-oriented R&D in Estonia.

2.2.4. The complementarity and substitutability of knowledge sources in innovation processes

The model used to assess the complementary use (H7 and H8) of knowledge sources for innovation processes is a simple one-way variance analysis (ANOVA), which is estimated using SPSS's general factorial procedure. The dependent variables are the average importance of knowledge sources. For each of the dependent variables, the means are tested among the relevance groups of other knowledge sources (four levels 0 – not used; 1 – used with low importance, 2 – used with medium importance, 3 – used with high importance to innovation). The null hypothesis tested is as follows:

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_k \text{;}$$

where μi is the mean of group i. The F statistic for this comparison is constructed as follows:

F = variation among the sample means / variation within the samples.

If the means of samples are far apart from each other, the F statistic becomes large and the null hypothesis is rejected. The procedure in SPSS enables us to perform the regression analysis along with the variance analysis.

There are several assumptions that should be fulfilled in order to perform the ANOVA – the samples should be normally distributed and the variances within samples equal (homogenous), and all observations should be independent. To assess whether or not the sample standard deviations vary significantly across the groups, a Levene's test needs to be conducted. Because the Levene's test is considered unduly sensitive, especially if the data is not normally distributed, the alpha should be set to 0.001 (see Tabachnick and Fidell, 1996). For example, if $p<0.001$, we conclude that the standard deviation or variances vary significantly across the groups, and thus there is a violation of the assumption called homogeneity of variance. On the other hand, if p>0.001, we conclude that insufficient evidence is available for proving that the standard deviation or variances vary significantly across the groups.

Table 47. The results of univariate ANOVA for internal sources as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
			(0)-(1)	–0.4238	
			(0)-(2)	–1.0630***	
		(0) –1.293***	(0)-(3)	–1.2629***	
		(1) –0.869**	(1)-(2)	–0.6392	
i_suppliers	1.935***	(2) –0.230	(2)-(3)	–0.2296	–
			(0)-(1)	–0.7340*	
			(0)-(2)	–1.2761***	
		(0) –1.720***	(0)-(3)	–1.7197***	
		(1) –0.986***	(1)-(2)	–0.5421	
i_customers	2.286***	(2) –0.444*	(2)-(3)	–0.4436	–
			(0)-(1)	–0.7513*	
			(0)-(2)	–0.5647	
		(0) –1.304***	(0)-(3)	–1.3040***	
		(1) –0.553	(1)-(2)	0.1815	
i_competitors	2.273***	(2) –0.734*	(2)-(3)	–0.7343	–
			(0)-(1)	–0.8167*	
		(0) –1.000	(0)-(2)	–1.000	7.515
i_universities	2.250***	(1) –0.813	(1)-(2)	–0.1833	0.023
			(0)-(1)	–0.9566**	
		(0) –1.000	(0)-(2)	–0.2258	6.589
i_R&D institutes	1.500***	(1) –0.183	(1)-(2)	0.7308	0.037
			(0)-(1)	–0.5966	
		(0) –0.887**	(0)-(2)	–0.8870*	
i_associations	2.100***	(1) –0.290	(1)-(2)	–0.2905	–
			(0)-(1)	–1.0376***	
			(0)-(2)	–1.2361**	
		(0) –0.694	(0)-(3)	–0.6944	
		(1) 0.343	(1)-(2)	–0.1985	16.276
i_consultants	1.833***	(2) 0.542	(2)-(3)	–0.7343	0.001
			(0)-(1)	–1.2207***	
			(0)-(2)	–0.8503***	
		(0) –0.374	(0)-(3)	–0.3741	
		(1) 0.847**	(1)-(2)	0.3704	
i_conferences	1.190***	(2) 0.476	(2)-(3)	0.4762	–
			(0)-(1)	–0.5920	
			(0)-(2)	–0.5382	
		(0) –0.886	(0)-(3)	–0.8861	
		(1) –0.294	(1)-(2)	0.0537	
i_journals	2.000***	(2) –0.348	(2)-(3)	–0.3478	–

***significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

With our data, the violation of the homogeneity of variance requirement is present in some models. Most commonly, some transformations are conducted to solve this problem in order to eliminate the heterogeneous variance, but in our case (where we do have some outliers that are very distant from the others) transformation would not work. For models with heterogeneous variance, the Kruskal-Wallis test (indicated as K-W test) is performed[54] – this test does not assume a normal distribution. The results of the K-W test are performed only if the Levene test showed that the assumption of homogeneity is violated. One can say in advance that in all equations, the null-hypothesis of equal means is rejected by the K-W test.

Once we have determined that differences exist among the means, post hoc range tests and multiple comparisons can determine which means differ. SPSS provides many comparison procedures that help to identify the different means. Multiple comparisons are performed for the average across the levels of the within-subjects factors. Here we use the Bonferroni method, which uses t-tests to perform pair-wise comparisons between group means, and also checks the overall error rate by setting the error rate for each test to the experiment wise error rate divided by the total number of tests. Hence, the observed significance level is adjusted for the fact that multiple comparisons are being made (see also SPSS 7.0 User manual for details).

By comparing means, the tests are performed that allow unequal variances (for example Tamhane's T2, Dunnett's T3 and a C-test[55]) – these are indicated by multiple comparisons only if the assumption of homogeneity is violated (because the Bonferroni method assumes equal variance).

In the interpreting the results, only statistically significant results are presented and discussed. It has to be noted that in discussing the results the importance of a knowledge source in innovation is described as the intensity of the use of the respective knowledge source for innovation. This might not be true in terms of inputs (intensity of contacts etc.), but rather in terms of outputs (intensity of the source in use in innovation activities).

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[54] Which is a nonparametric test testing whether several independent samples are from the same population 8meaning have equal means).

[55] For more detailed description of the tests, see also SPSS 7.0 Manual.

Table 48. The results of univariate ANOVA for suppliers as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
i_customers	2.143***	(0) –1.388*** (1) –0.543* (2) –0.090	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.8453* –1.2979*** –1.3881*** –0.4526 –0.0902	–
i_competitors	1.455***	(0) –0.501 (1) 0.465 (2) 0.725**	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.9669*** –1.2264*** –0.5014 –0.2595 –0.7249	30.403 0.000
i_universities	2.750***	(0) –1.358** (1) –0.617	(0)-(1) (0)-(2) (1)-(2)	–0.7417** –1.3583** –0.6167	10.295 0.006
i_R&D institutes	2.500***	(0) –1.089 (1) –0.192	(0)-(1) (0)-(2) (1)-(2)	–0.8964** –1.0887 –0.1923	8.485 0.014
i_associations	2.100***	(0) –0.748** (1) –0.052	(0)-(1) (0)-(2) (1)-(2)	–0.6958** –0.7481 –0.0524	8.319 0.016
i_consultants	2.000***	(0) –0.685 (1) –0.176 (2) 0.375	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.8617** –1.0602* –0.6852 –0.1985 0.3750	13.283 0.004
i_conferences	1.952***	(0) –1.361*** (1) 0.011 (2) 0.119	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–1.3711*** –1.4796*** –1.3605 –0.1085 0.1190	–
i_journals	2.333***	(0) –1.232** (1) –0.422 (2) –0.166	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.8105*** –1.1161*** –1.2321 –0.3056 –0.1159	23.603 0.000

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

The results are described in Tables 47–55 and in Appendices 15–23. From Table 47 and Appendix 15, we can see that mostly external knowledge sources complement internal sources, except for consultants and conferences. Consultants seem to be a complement in the low and medium intensity of internal sources, but substituting if they are used besides above-medium intensity of internal sources (see also Appendix 15). However, since the differences in the means are not significant (see Table 48), the substitution argument is not verified.

Conferences seem to be substitutes for internal sources, but also from a certain intensity level onward. Conferences are only used by firms with at least medium use of internal sources (see Appendix 15), but again, the differences in the means are not significant. Using these results, we can conclude that generally, internal and external sources complement each other; however, at high intensities some external sources have a decreasing marginal contribution to innovation (suggesting an inverted U-shaped curve in the 2nd quadrant in Figure 11). This result supports hypothesis H8.

Table 49. The results of univariate ANOVA for customers as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
i_competitors	2.545***	(0) –1.983*** (1) –0.985*** (2) –0.571*	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.9775*** –1.4119*** –1.9830*** –0.4114 –0.0.5711	–
i_universities	2.500***	(0) –1.383*** (1) –0.100	(0)-(1) (0)-(2) (1)-(2)	–1.4783*** –1.3833** –0.1000	–
i_R&D institutes	2.500***	(0) –1.363* (1) 0.115	(0)-(1) (0)-(2) (1)-(2)	–1.4783*** –1.3629 0.1154	–
i_associations	2.300***	(0) –1.254*** (1) –0.205	(0)-(1) (0)-(2) (1)-(2)	–1.0489*** –1.2537*** –0.2048	–
i_consultants	2.167***	(0) –1.148*** (1) –0.108 (2) 0.583	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–1.0403*** –1.7315*** –1.1481* –0.6912 0.5833	–
i_conferences	1.333***	(0) –0.905*** (1) 0.222 (2) 0.786***	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–1.1270*** –1.6905*** –0.9048*** –0.5635 0.7857**	–
i_journals	2.333***	(0) –1.536*** (1) –0.451 (2) –0.333	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–1.0849*** –1.2025*** –1.5359* –0.1176 –0.3333	–

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

Most of the knowledge sources are similarly complements to suppliers; exceptions being competitors, consultants and conferences (see also Table 49 and Appendix 16). Consultants are used by firms with more than medium intensity of the use of suppliers for innovation, but the use of consultants as knowledge sources with high intensity is found to be evident in firms with medium intensity of the use of suppliers knowledge. Similar results can be seen in the case of competitors, who are complementarily used by firms with slightly less than medium intensities; however, the reliance on competitors with very high intensity occurs in firms with less than medium intensities of supplier collaboration. However, the differences in means are not significant. The results for conferences indicate that the difference between no use and use with high intensity are significant, but the differences between intensity groups do not play a relevant role. Therefore, suppliers and other external sources are used to complement innovation processes.

In the case of consumers as knowledge sources, other external knowledge sources are used as complements, except conferences and consultants, but also R&D institutes (see Table 50 and Appendix 17). As in the case of suppliers, consultants are used at a low and high intensity by firms who use consumers with medium intensity for innovation. Similar results but, at a lower intensity of use of consumer knowledge are found to be evident in the case of conferences; however, here the differences between medium and high intensity are statistically significant and therefore we can conclude that conferences substitute customer knowledge between the medium and high intensity of use. In the case of R&D institutes, there is a difference in means for not used at all, but use at different intensities shows no significant differences. The results concerning customers generally also support H9, but the only exception is the role of conferences, which seem to be a substitute at higher intensities of customer knowledge use.

Table 50. The results of univariate ANOVA for competitors as a dependent variable

Factors	Parameter Estimates		Multiple comparisons		K-W test
	Intercept	B	Difference in means		Sig
i_universities	1.250***	(0) –0.433 (1) –0.950*	(0)-(1) (0)-(2) (1)-(2)	–1.3833*** –0.4333 0.9500	–
i_R&D institutes	1.000	(0) –0.513 (1) 1.231*	(0)-(1) (0)-(2) (1)-(2)	–1.3840*** –0.1532 1.2308	–
i_associations	1.600***	(0) –0.776** (1) –0.124	(0)-(1) (0)-(2) (1)-(2)	–0.6521** –0.7759* –0.1238	–
i_consultants	1.667***	(0) –0.889** (1) –0.196 (2) 0.458	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.6928** –1.3472*** –0.8889 –0.6544 0.4583	–
i_conferences	1.143***	(0) –0.776*** (1) 0.116 (2) 0.280	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.8919*** –1.0612*** –0.7755*** –0.1693 0.2857	–
i_journals	2.667***	(0) –1.996*** (1) –1.549*** (2) –1.058*	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.4468 –0.9378*** –1.9958*** –0.4910 –1.0580	–

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

When analysing the competitors, they seem to be complements with industry associations and journals, but substitutes in high intensities for conferences, consultants, R&D institutions and universities (see also Appendix 18). However, the differences in means are not statistically significant, so we can conclude that generally competitors are used along with other external knowledge sources as complementary.

Universities generally complement other external sources of knowledge except for R&D institutions and conferences (see Appendix 19). In the case of both, the differences in means are statistically significant. In addition to R&D institutes, conferences are also used to obtain similar knowledge as from universities.

Table 51. The results of univariate ANOVA for universities as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
i_R&D institutes	0.500**	(0) –0.435* (1) 0.577**	(0)-(1) (0)-(2) (1)-(2)	–1.0124*** –0.4355 0.5769*	–
i_associations	0.600***	(0) –0.563*** (1) 0.019	(0)-(1) (0)-(2) (1)-(2)	–0.5820*** –0.5630*** 0.0190	47.772 0.000
i_consultants	0.833***	(0) –0.815*** (1) –0.304* (2) 0.042	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.5109*** –0.8565*** –0.8148*** –0.3456 0.0417	69.019 0.000
i_conferences	0.048	(0) –0.048 (1) 0.101 (2) 0.381***	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.1481 –0.4286*** –0.0476 –0.2804** 0.3819***	23.220 0.000
i_journals	0.667***	(0) –0.654*** (1) –0.284 (2) –0.362	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.3697*** –0.2917** –0.6540*** 0.0870 –0.3623	–

***significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

By looking at the results in Appendix 20, the complementarity of R&D institutes with industry associations and journals seems evident. In addition, the substitutability of consultants and conferences is also seen, which is also statistically significant (see Table 51). The results imply that the consultants and conferences are offering knowledge that is similar to that offered by R&D institutes and are used interchangeably by Estonian wood sector firms. As the results in section 5.2 show, the R&D institutions (contrary to the expectations) are used to gain market-related information; this is also offered by conferences and consulting firms. From the above we can find partial support for H9 by recognizing that there are some minor exceptions to that rule.

Table 52. The results of univariate ANOVA for R&D institutes as a dependent variable

Factors	Parameter Estimates		Multiple comparisons		K-W test
	Intercept	B	Difference in means		Sig
i_associations	0.600***	(0) –0.563*** (1) –0.267**	(0)-(1) (0)-(2) (1)-(2)	–0.2963*** –0.5630*** –0.2667	33.683 0.000
i_consultants	0.333***	(0) –0.306** (1) –0.039 (2) 0.542***	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.2663*** –0.8472*** –0.3056 –0.5809*** 0.5417***	51.795 0.000
i_conferences	0.095	(0) –0.095 (1) –0.021 (2) 0.214**	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.0741 –0.3095*** –0.0952 –0.2354** 0.2143	16.696 0.001
i_journals	0.667***	(0) –0.629*** (1) –0.461** (2) –0.449**	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.1679 –0.1794 –0.6287*** 0.0115 –0.4493	18.994 0.000

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

Consultants are used in a complementary way with industry associations and journals (see also Appendix 21), but as substitutes with conferences (see also Table 53). This confirms the results discussed previously that conferences and consultants offer similar knowledge to Estonian wood sector firms.

Table 53. The results of univariate ANOVA for consultants as a dependent variable

Factors	Parameter Estimates		Multiple comparisons		K-W test
	Intercept	B	Difference in means		Sig
i_associations	1.000***	(0) –0.806*** (1) –0.048	(0)-(1) (0)-(2) (1)-(2)	–0.7579*** –0.8056*** –0.0476	23.363 0.000
i_conferences	0.190	(0) –0.170 (1) 0.476** (2) 0.476**	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.6463*** –0.6463*** –0.1701 0.0000 0.4762*	26.406 0.000
i_journals	1.000**	(0) –0.873** (1) –0.206 (2) –0.522	(0)-(1) (0)-(2) (0)-(3) (1)-(2) (2)-(3)	–0.6675*** –0.3517 –0.8734 0.3159 –0.5217	27.254 0.000

***significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

Industry associations are used together with journals (see also Appendix 22), but some doubts arise about substitution with conferences, but since the means are not statistically different (see Table 54), it cannot be verified.

Table 54. The results of univariate ANOVA for industry associations as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
			(0)-(1)	–0.3666**	
			(0)-(2)	–0.5068***	
		(0) –0.197	(0)-(3)	–0.1973	
		(1) 0.169	(1)-(2)	–0.1402	20.864
i_conferences	0.238**	(2) 0.310**	(2)-(3)	0.3095	0.000
			(0)-(1)	–0.5376***	
			(0)-(2)	–0.6015***	
		(0) –0.616**	(0)-(3)	–0.6160	
		(1) –0.078	(1)-(2)	–0.0639	35.798
i_journals	0.667**	(2) –0.014	(2)-(3)	–0.0145	0.000

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

Journals and conferences are used to complement each other (although Appendix 23 raises some doubts). The results in Table 55 show that the differences in means are not significant and therefore we can conclude that they are used to complement each other.

Table 55. The results of univariate ANOVA for journals as a dependent variable

	Parameter Estimates		Multiple comparisons		K-W test
Factors	Intercept	B	Difference in means		Sig
			(0)-(1)	–0.5684***	
			(0)-(2)	–1.1293***	
		(0) –0844**	(0)-(3)	–0.8435***	
		(1) –0,275	(1)-(2)	–0.5608***	48.702
i_conferences	0.905***	(2) 0.286	(2)-(3)	0.2857	0.000

*** significant at the 1% level; ** significant at the 5% level, * significant at the 10% level

By summarizing the results of the complementarity issue, the complementarity between internal and external knowledge sources seems evident (supporting H8). At the same time, most of the external sources also seem to complement each other (supporting H9). There are interesting exceptions found in some external knowledge sources. In the case of public sources – R&D institutes, universities, consultants and conferences – there seems to be sustainability of use for innovation activities. This means on the one hand, that those sources are offering similar knowledge to firms, but on the other hand, this result is certainly valid only in case of the Estonian wood sector. The reason for this lies in the public sector's inability to offer knowledge that contributes to the knowledge of firms in the field of testing, novel research equipment etc., and therefore the firms obtain consultancy from them about the markets rather than the technological help they could really use.

This result has important policy implications, but also for developing sectoral innovation systems. Firstly, it indicates the irreplaceability of different types of actors in the innovation system (on cannot rely on supporting some actors and ignoring the others), and second, in the case of the under-development of some actors, these are starting to fulfil the functions of other actors and fail to contribute to the innovation according to their core competences.

2.3. Policy implications for fostering the knowledge transfer in the wood sector

2.3.1. General principles and practices in fostering knowledge exchange in the context of the Estonian wood sector

The traditional theoretical motivation for S&T policy has been seen by questioning the market failure or subobtimality of R&D efforts in the economy, and mostly agreeing that there is underinvestment in R&D as an outcome of market allocation (Nelson, Soete, 1988). This argument has been used to justify public policies in support of R&D activities in firms and research institutions generally. However, if we take into account the theories of the firm regarding firms as repositories of knowledge and innovations as one outcome of knowledge production (occurring in firms via various different activities, not only R&D), the policy of encouraging innovation and technological change should be seen more broadly. As discussed in section 1.1.1, our understanding of innovation processes has advanced from linear innovation models (science-push or market-pull models) to more systemic ones (chain-link or interactive models), and this has transformed the respective policy approaches from science and technology policies to innovation policies (see e.g. Lundvall & Borrás, 2007) that aim to remedy specific failures between various actors in the respective national, regional or sectoral setting. Rametsteiner and Weiss (2006) find, in exploring respective policies in the countries of Central Europe, that explicit policies and strategies that would provide systematic innovation support for wood-related sectors are rare and those innovation support measures that do exist are fragmented and not coordinated.

Storper (2002:150) sees the goal of policy for traditional products to be the continuous adaptation of products and processes, especially through product differentiation or moving up in price-quality ratio in order to respond to the inevitable and ongoing entry of competitors. As argued by Zysman (1996), distinctive institutional structures in different nation states stemming from historically determined political and economic development define the choices that are available to individual actors (individuals, firms, organisations) in responding to new economic or technological trends. The institutions are essential for accumulating the acquired knowledge and skills into collectives of workers organised into organisations (Wolfe, Gertler, 2002:10). As discussed by Hodgson (1993:234), habits and routines within firms constitute an important mechanism for preserving and transmitting skills and technological learning within the firm.

In discussing policy issues, the role of institutions[56] becomes highly relevant because nation-specific institutional structures create specific patterns of incentives and constraints for innovative activities[57].

Wolfe and Gertler (2002:12) see two approaches to institutions in terms of the knowledge and learning perspective: one looks at institutions as systems of organising and constraining the social behaviour of agents by reproducing and transmitting existing norms and values; and second sees institutions as mechanisms embedding and preserving collective social knowledge of a variety of subjects. The first approach views the institutions as impeding the process of change via a rigidity rooted in institutional systems. The second approach sees institutions rather as vital mechanisms for preserving and transmitting knowledge relevant to change and adaptation. The underlying point of difference lies in the understanding of the capabilities of institutions to change.

The ability to change consists of two elements – the ability to learn and the ability to forget. Johnson (1995) sees the latter as important as the former in periods of rapid economic and technological change, because the inability to forget can pose a risk for an irrational lock-in of resources (Johnson, 1995:30). This has been illustrated by international evidence from Gertler (1993), who

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[56] There is a discussion in recent institutionalist literature in the scope of defining institutions. One (North, 1990 and Williamson, 1985, but more recently Edquist and Johnson, 1997) takes a more narrow approach towards institutions (that shape the patterns of behaviour such as norms, rules, habits etc) separating them from organisations (such as firms, universities and other organisations). The other strand stemming from recent literature on the sociology of organisations (DiMaggio, Powell, 1991) considers organisations as institutions because they reflect changes in the broader institutional settings they are embedded in. Hence, the organisations are nested within and shaped by the broader institutional environment where they are situated. The innovation-systems perspective agrees with the latter approach, where institutions and organisations are used interchangeably (Wolfe, Gertler, 2002:10).

[57] The capability of individuals, firms, regions and nations to learn and adapt to rapidly changing economic conditions determines their future success in the global economy (Lundvall, Borras, 1998). Therefore, the role of institutions and their ability to change becomes crucial in conditions of rapid economic and technological change. Economic and technological changes do not occur in isolation from the social and institutional transformations.

points to the great difficulties that manufacturers in old, mature industrial regions have in accepting new technologies.

Whether institutions within a nation or region can support or hinder learning becomes of crucial importance. For the sake of innovation and technological change, the key challenge is to identify those socioeconomic and political coalitions that support change, and analyse how they contribute to this process (Hall, 1997:183). The underlying argument of this positive impact is the recognition of the importance of tacit knowledge, which is accessed and transferred more easily through face-to-face contacts and proximity fosters such contacts, but also such contacts take place within the context of social networks based on trust and shared culture (Maskell et al., 1998). As important as the market exchange, Dosi (1988), Storper (1995), Formica (1995) also consider the non-market forms of interaction, called untraded interdependencies.

The institutions influence learning processes and knowledge exchange. The following examples are considered especially important regarding the situation in the Estonian wood sector.

At first, *cultural background* – as generally noted by Estonian managers, they lack any tradition of cooperation and some managers consider this a national or cultural characteristic. Primarily, the lack of trust and lack of gentleman-like behaviour in the other party (that has sometimes also been confirmed in past relationships) [1, 4, 8] was recognised (not keeping to deadlines, defective goods in jointly supplied lots etc.) [4]. Here, the only way to improve this kind of cooperation is by revealing the joint interests and gains in creating and maintaining long-term relationships. The fact that such relationships are desirable and work in favour of both partners is recognised by the firms; however, the creation of such relationships and trust takes a long time [3], which is not considered worth the investment. In some cases, the cooperation is hindered by an overly narrow view of the environment (local rather than global), which causes the failure to recognise broader cooperation potential [8, 14]. If one compares managers that are cooperating actively with their competitors with those managers who consider cooperation impossible, one can see that cooperating managers had some common history before becoming entrepreneurs and competitors (at university together, a joint project etc), where the mutual trust that is today the basis for strong cooperative relationships had developed.

It is argued by Gertler (2002) that behind this cultural background there is a more fundamental influence of key importance to social learning – a shared set of rules, expectations and norms, which do not simply arise from a common history and culture, but from a common *macro-regulatory framework* facilitating the cooperation between firms and shaped by the institutions and interventions of the state. Gertler links the origins of cultural differences to the nature of social institutions that regulate business financing (different time horizons for expected payback time), labour relations (the role of workers in the decision-making process of firms: direct and indirect; the use of internal vs. external labour markets) and corporate governance in firms. Different 'cultures' are therefore a response to the concrete macro-regulatory framework.

A similar point of view is expressed by Morgan (1996), who sees the 'culturalist' interpretation as inadequate. Hence, social capital is not an inherited asset, but needs to be developed and this process is influenced by the macro-economic regulatory framework. Therefore, as discussed by Gertler (2002:130–131), as long as labour market regulations discourage investment in training, the firms will not cooperate in training, but rather compete for talented and skilled labour. If the capital market will impose short horizons, investments in long-term relationships will not occur. When sector-specific skills are needed, or if there is a high level of local labour market flexibility, there can be strong negative externalities: producers do not want to invest in training because they fear they would loose the employees they have trained. In Estonia, as discussed by Eamets and Masso (2004), the labour market is quite flexible. In the face of rapid skill changes, no single producer can impact the respective changes in skill supply and a downward trend in competitiveness can occur (Storper, 2002:147). Public organisations can provide training, make strategic changes in the direction of training, make jobs more secure in certain locally concentrated sectors in the case of high labour market flexibility.

By considering other macroeconomic policy issues, most of the managers interviewed are pleased with the general corporate taxation policy and they fear that if this policy is changed, there is a threat of decreasing investments in Estonian firms, especially in affiliates of MNCs. The issue of taxing individual income from forest management is also relevant for the whole cluster, while private households own approximately 35% of the forested land in Estonia[58]. It has been found that there is a need to change the tax base from sales turnover (as it is currently) to profits in the case of private households to increase the incentive to declare actual forest revenues and to enhance the interest in forest management among private households in general. It is common to all countries that some economic sectors are preferred over others via public policy; however, Porterian cluster policy advice suggests not supporting industries directly and distorting the respective market signals. The same problem has been raised by wood industry managers – while wood and forest industries are relevant employers in rural regions, the public grants for agriculture (that have emerged with EU-accession), have decreased their competitiveness on factor markets (mainly, for labour).

[58] Here one has to note that many of them are sole proprietors taxed by similar principles as the firms. However, as estimated by EFIA, the government earns less tax revenues from forest management in the annual amount of 60 m EEK. This question should be viewed more broadly as one related to the more effective and sustainable management of the resources of the country. (See EFIA, 2006: 7)).

Accelerated changes in ownership. Considering the dynamic capabilities of firms, the process of accelerated capital mobility (and FDI in particular) carries with it two contradictory impacts. From one perspective, new opportunities for learning arise: FDI can catalyse production locally and through its presence stimulate innovation via knowledge spillovers and the transformation of information and technology through supplier-client linkages (Mytelka, 2002:102). According to the McKinsey Global Institute (1993), transplants from leading producers that contribute directly to higher levels of domestic productivity prove that high productivity levels can be achieved with local inputs, putting competitive pressure on domestic competitors and transfer knowledge of best practices to other domestic firms through the natural movement of personnel.

From another viewpoint, it makes long-term interactions and innovation networking more difficult (Mytelka 2002:92). At worst it can crowd out local competitors, strip proprietary knowledge and other assets from these firms through mergers and acquisitions, engage in a variety of market-distorting practices with highly negative effects for achieving broader social and economic goals (Mytelka, 2002:102). The latter becomes important considering the competitiveness of SMEs. While the former impact is well vested in the extensive literature on knowledge spillovers, the empirical evidence in favour of the latter has been brought out by Mytelka (1999). Considering the broader perspective, the ability of local economies to remain independent of the strong impact of multinationals is questioned (Amin, Robins, 1990). In the Estonian case (see section 2.2.3 for a discussion of competitors as knowledge sources), the analysis showed that in the earlier period of the study (1998–2000), members of the concern seemed not to link with other firms in the sector, while in the latter study period (2002–2004), they were more actively cooperating and exchanging knowledge with competitors and industry associations were becoming more embedded in the local economy and certainly increasing knowledge spillovers.

The problem seem to be rooted more in the kind or goal of FDI that was flown into the Estonian wood sector. As Mytelka and Delapierre (1999) have found, the knowledge-based networked oligopolies that are behind knowledge oriented FDI share common characteristics positive to the development of the local economy. They involve collaboration in the generation, use and control of the evolution of new knowledge and focus less on creating static size barriers to entry, but rather more on shaping the future boundaries of industry and technological trajectories, standards, and rules of competition within the industry (which can be sources of dynamic entry barriers). In addition, they are composed of networks (alliances) rather than individual companies and can dynamically form within or across industry segments, and sometimes do form both at the same time by including new relevant actors and eliminating others whose resources are no longer critical. The purely production-cost advantage seeking FDI does not share many of the positive characteristics.

From the discussion above, the following groups of measures can be shown to support innovation and knowledge exchange.

1. *Promoting networking* between business partners for innovative activities to enchance technology transfer. This is especially relevant in wood industries in order that incremental innovation can occur more rapidly. Nationally legislated labour market institutions facilitate indirect cooperation between firms in the same industry through industry associations or chambers in which membership is mandatory. As discussed by Wever (1995:11), these institutions create incentives that support the sharing of knowledge and organisational innovations in Germany and Japan.

The following mechanisms for creating the necessary precedents and conventions exist for learning within the innovation system to work (Storper, 2002:139–148). Talk, as communicative interaction for transmitting information, preferences, but also to achieve mutual understanding (Lundvall, 1990). It is cheap and low risk; however, it takes time and effort and has no quick pay-offs, especially when the history of relations has been bad (Storper, 2002:140). When there are no conventions of talk, some small, repeated experimental interactions might be useful for getting started (Storper, 2002:142). In such cases the likelihood of getting the actors to interact as if there were confidence is increased by the depth and breadth of their knowledge of each other (Storper, 2002:142). The depth of the knowledge is not so uniformly dependent on the geographic dimension, but the breadth is. The role for policy in this regard is to create precedents that build confidence and therefore help to deepen and widen the conventions (Storper, 2002:155).

2. *Developing a local supply of expertise* (field-specific training and focusing on educational and research institutions), but also developing entrepreneurship (especially for small firms). Interestingly, Faulkner et al (1995:13) in reviewing the literature conclude that an increase in industry and public sector research collaboration results not only from the mutually beneficial knowledge exchange, but also from the inability of governments of industrialised countries to sustain previous (but also in some cases absolute) growth levels in research funding. However, as they additionally find (Ibid, p.3), any policy that is based on the understanding of what firms need from universities in different industries and targeting the areas where the linkage is most appropriate, yields higher benefits compared to a universal policy.

There are several factors contributing to the situation where the supply of education does not match the needs for qualified personnel in the Estonian wood sector, and therefore, firms have to train their employees mostly internally. Regarding a training support programme, firms do not consider it to be sufficient to support larger-scale projects that would really make a difference (for example, changing to a completely new IT solution [1, 5]). However, several firms stated that with or without the support, they see a need for innovations in those fields. Regarding educational policy, the managers would expect better matching between the proportions of specialists in wood-related fields with the share those industries have in the economy (this concerns especially tertiary education). From other aspects, all levels of education should encourage innovativeness and problem-based learning, because that is where the barriers for innovation have been felt to be the strongest [9]. The managers also recognised the need for some complementary training for top-managers (for example, how to more efficiently use external knowledge such as consultants etc.) [8]. Also, the relevance of mentor programs was recognized and the willingness to contribute to those programs [9].

The government and universities jointly could improve the conformity of R&D and policy studies conducted by the public sector, mainly in analysis and projections of labour market developments. In addition, the industry would like to have at least some public R&D specialization in fields that are economically important to Estonia, such as wood-related sectors. Often, the information relevant for industry is in the hands of some government agency (such as Enterprise Estonia), but this knowledge is not disseminated to the firms; the firms often don't have the resources to analyse the raw data from the market. [8]

3. *Supporting and concentrating* such *services* that are too expensive for single firms (e.g. systematic market research, export marketing, technology research and also technology sharing). The Estonian government like many in the CEE countries is concerned with stimulating the new technology-intensive sectors, but not with any interaction between such sectors and traditional sectors. This has created an interventionist approach to S&T policy where resources have been forced into limited technological areas. The new information and communication technologies are one example of such core factors that diffuse throughout the economy creating a growing system of technical, social and managerial innovations (Freeman, Perez, 1988). New technology demands new organisation of production to complement those new technologies and the additional restructuring of the entire socio-political infrastructure (Wolfe, Gertler, 2002:12); therefore, interaction between different sectors needs to be supported for smoother spillover of these new technologies to the rest of economy.

The role of services offered by municipal governments emerges only with regards to the infrastructure – often the firms experience problems with water, sanitation, roads, internet, public transportation etc. Since the managers are very well aware of the scope of the budgets in local governments, they do not have overly high expectations of local public investments in infrastructure. In most cases the managers have good cooperative relationships with municipal governments. Despite that there were some cases identified, where unresolved disagreements between multiple local governments have hindered a firm's operation and development [15]. Small municipalities are considered not able to achieve the required level of infrastructure investments, and therefore, the publicly funded support program for infrastructure investments in firms is mostly welcomed on behalf of the entrepreneurs. The role of development centres set up by the county governments was found to be irrelevant for most of the managers interviewed, several of the managers didn't even know of the existence of such centres. The reason for this could be that these centres are more oriented towards SMEs and start-ups, which were not the main target group of the interviews. Regional publicly initiated cluster-initiatives (like the South-Estonian Wood Cluster) have not been successfully put into practice as recognized by participating managers.

The public grants have been received mainly for infrastructure, visiting trade fairs and training support. Public support for technology procurement has only been used by one firm and the donor foundation was ERDF [7]. However, there were several firms that recognise the need for support especially in the area of new technologies, R&D activities and improvement of working conditions for the employees (because woodworking activities are often associated with noise, dust, etc and the improvement of working conditions would decrease the disadvantage to the labour force) [4,8,15]. The need for support in buying new technologies was recognised by SMEs, larger firms noted that since the process of receiving respective grants are too slow [5], they cannot count on public support because the speed at which they need to react to changes in their business environment is more rapid [9, 11]. Managers also mentioned that they would also expect the public institutions managing the grants given to firms to be more operative and effective [5, 10]. Hence, the speed and flexibility of the process of grant application is relevant to better match the grant to the firm's needs. The public policy here cannot be too specific, because rapidly changing technologies make it very hard to predict future technological needs; it is even more difficult for the public sector to try to determine the technological development of the sector.

2.3.2. Estonian S&T policy in the context of the wood sector

Estonian S&T policy review[59]

Estonian R&D and innovation strategy documents determine the general financing strategy of R&D expenditures, whereby not only the prognosis of public funds, but also expected private funding is specified (see general trends in Table 56). The measures of Knowledge-Based Estonia (KBE), a strategy document for 2002–2006 concentrate on supporting R&D projects in firms and universities, strengthening the knowledge base in universities and encouraging

[59] This sub-section draws on the author's analysis published in Teder et al. (2006).

cooperation between industry and academia. The second KBE encompasses a wider variety of measures by adding support for cluster initiatives, funding for the dissemination of innovations, but also increased funding for improving innovation awareness in the general public. The second KBE is certainly a step towards a more systemic approach to innovation, but it still omits some crucial activities related to entrepreneurship and networking generally held as relevant for systems employing an innovation approach (Edquist 2005).

Both documents bring out specific sectors/fields that are targeted; however, forest-related sectors are not mentioned. It is evident from textual analysis that both documents of the KBE are well integrated concerning the strategies in higher education and entrepreneurship (as is also evident from the division of funding volumes by the ministries), but at the same time contains no links to rural development or forestry (including the respective development strategies). Therefore, the conclusion that KBE is not aligned with and integrated specifically towards the forest sector seems appropriate.

As in other catching-up economies, Estonian innovation strategy is targeted towards user-friendly information and communication technologies and the development of an information society, biotechnology (in Estonia, biomedicine) and materials technology. The problem here is that the strategy imitates similar strategies in other countries without aligning with the structure of the national economy and without seeing the importance of traditional industries as customers of high tech industries. (The first problem is more deeply discussed in Edquist, 2001; and the second in Von Tunzelmann and Acha, 2005; and Hirsch-Kreinsen et al., 2005.)

As already mentioned, the national innovation policy of Estonia is targeted towards high–tech enterprises[60]; therefore, there are very few services that most wood sector firms can use. Measures supporting incremental innovations have been absent so far. As a result, many enterprises do not perceive that the innovation policy concerns them. Innovation awareness among Estonian entrepreneurs is rather low; innovation is perceived as something high-tech, centred on R&D and distant and connected with IT, banking and telecommunications rather than with the traditional industries of the economy (Kalvet et al. 2005).

[60] This sextion draws in pp. 12–13 on J. Masso and K. Ukrainski, *Private Sector Interaction in the Decision Making Processes of Public Research in Estonia*, Unpublished manuscript, (2006).

Table 56. R&D expenditures in 2002–2010 (million EUR)*

R&D Expenditures	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total expenditure	52.1	64.2	85.8	110.9	139.7	*175.8*	*230.8*	*315.6*	*351.8*
Total expenditure, % of GDP	0.8	0.9	1.1	1.3	1.5	na	1.5	na	1.9
Public sector expenditure	41.7	51.4	64.4	83.2	97.8	83.0	118.4	192.2	213.5
Share of public sector, %	80.0	80.0	75.0	75.0	70.0	*47*	*51*	*61*	*61*
State budget allocations	31.8	39.2	45.6	56.5	64.8	83.0	118.4	192.2	213.5
of which Ministry of Education and Research	26.4	27.5	29.4	35.2	38.3	49.6	72.3	139.6	155.4
of which Ministry of Economic Affairs and Communications	4.5	10.9	15.3	20.5	25.6	26.3	39.9	46.3	51.9
of which other ministries	0.9	0.9	0.9	0.9	0.9	7.0	6.1	6.2	6.2

Source: Knowledge-based Estonia 2002–2006 p. 32; Knowledge-based Estonia 2007–2013, p.35. *Authors' calculations based on presented data are shown in italics. The years 2011–2013 are not added because they do not include details respective strategies.

Though the Estonian NIS has been acknowledged in some cases for its quick development in the right direction, the exclusively high-tech orientation of its innovation policy has also been criticized by external experts (Radocevic, 2002), as has its orientation towards financing basic research instead of taking a more practical strategy of focusing on practical scientific applications. Hernesniemi (2000) stated the following weaknesses in the Estonian innovation system: 1) low awareness (low awareness on the part of firms of the need for technology development and the unwillingness of politicians to invest in technology development); 2) aside from the overall low levels of funding, the over-allocation of funds towards basic research and to sciences not related to technology; and 3) poor functioning of technology policy management and non-existent contacts with firms. The situation is largely as a result of the Soviet heritage, where R&D activities were carried out in big institutes, and not in enterprises, and not where experimental R&D activities and development based on customer feedback were commonly practiced. That is the major reason for the low level of private sector cooperation with universities and of their lack of involvement in research policy.

Although, KBE 2007–2013 could be indirectly considered to be targeted more directly towards the forest sector as it recognizes the need to support innovative attempts in both new and traditional industries (to which forest-related sectors certainly belong). For example, to respond to the needs of traditional industries, starting in 2007, support is being extended for testing and certification procedures, design and productivity management projects, etc. The strategy also aims at strengthening the competences and knowledge base of firms for strategic innovation management and development activities by supporting the engagement, training and counselling of specialists, including development specialists from Estonia, but also from abroad. By developing industry clusters, priority is established for active use of key technologies that lead to growth in productivity (Knowledge-based Estonia, 2007). The funding for the above-listed measures comprises 22% of the total funding for KBE 2007–2010.

The extent of the fragmentation / duplication of R&D efforts[61]

The analysis in sections 2.1 and 2.2 brought out the idea that the public R&D base is exploited to a lesser extent for innovation in the Estonian wood sector compared to its Finnish counterpart. One reason for this is found in the low absorptive and innovative capacities of Estonian companies; however, the other reason lies in the very different public sector R&D specialisation in these two countries. Generally in Europe, forest research is considered to be fragmented (Houllier et al. 2005), and this is also true for Estonia, although additionally, the

[61] This aspect has not been taken up in comparative studies of both countries presented in 2.1.3 and therefore only some aspects of R&D efforts in both countries are commented here.

public R&D efforts are extremely weakly developed in the fields connected with wood industries.

The R&D specialisation of Finland is rather different with respect to wood industries compared to Estonia. In 1995, the wood sector was nationally targeted in Finland as one of the most competitive sectors of the economy and has been supported via the cluster-facilitating program *Wood Wisdom* since 1998. The funding has been around 200 Million FIM from which 57.2% was financed from the public sector (Pentikäinen, 2000). The project incorporated universities and research institutes in research-oriented cooperation with firms and the analysis of the preliminary results of this cooperation has recognised that it has been relatively successful in this regard (Ibid, p. 60).

In contrast, the Estonian sectors under discussion have not received public support for their R&D investments or R&D cooperation programs. In 1998–2004[62], the majority of R&D investments have been made by private companies in the sector, and only occasional financing from other sources (also foreign) can be identified[63]. In 2004–2005, there was one R&D project supported in the field of the construction of wooden element houses. Wood sector firms have received support for various other activities (consultation, training, infrastructure, start-up, export promotion), whereby they have been quite active in applying for these other measures (in 2004–2005 9% from the total number of supported projects by Enterprise Estonia were granted to wood sector firms) (calculations based on Tiits (2007: 138–139).

Public R&D efforts are difficult to analyse specifically in wood-related fields, because they fall in different scientific fields (agriculture, engineering, material sciences, chemistry etc). Considering the general supply of R&D resources in both countries, Finland has an advantage – the statistics considering the two countries' R&D specialists' supply is rather different. The total number of researchers per 1000 in the active population is 7 in Finland and 4 in Estonia, at the same time, the share of scientists and engineers is 12 and 10 percent, respectively. The proportion of graduates in technology, engineering

[62] This analysis is based on the data from the electronic database of the Statistical Office of Estonia [www.stat.ee].

[63] For example, the IPPC project, a joint Estonian-Danish undertaking financed by the Danish Environmental Support Fund (DESF) was designed to deal with the environmental infrastructure problems in Estonian industry, whereby one of the target industries was the furniture industry, in which industrial processes were surveyed and the best available technical proposals were made to implement the EU IPPC directive (according to the report, the main costs of implementing the directives were seen in replacing old and worn out equipment (Economic Commission for Europe, Committee on Environmental Policy, Second environmental performance review of Estonia, (2001: 97).

and construction is not different[64]. However, as discussed by ILO scientists (ILO, 2001), wood-related educational profiles face difficulties in attracting enough students in all EU countries. In Estonia, the number of graduates in the wood (material) technology field has decreased drastically in recent years (down to an annual number of approximately 5 specialists), which is certainly not enough to satisfy the industry needs. The lack of university educated technicians in the respective field can cause a drop in the proportion of workers with a higher education in the long run (unless it is compensated by using specialists from abroad as is currently done by one interviewed paper mill, where the highly skilled specialists in paper technology are called in from Russia (Botvinkina, 2003))[65].

Wood-related scientific research in Estonian universities is extremely weakly developed, especially in wood technology and processing, as was recognised when setting the developing strategies for the wood sector (Ministry of Economic Affairs, 2003), but also in business-related research in those sectors, which has been non-existent (see Figure 12). The research has been conducted mainly in two universities, mostly in the field of forest research, but to a lesser extent also in wood (material) technology.

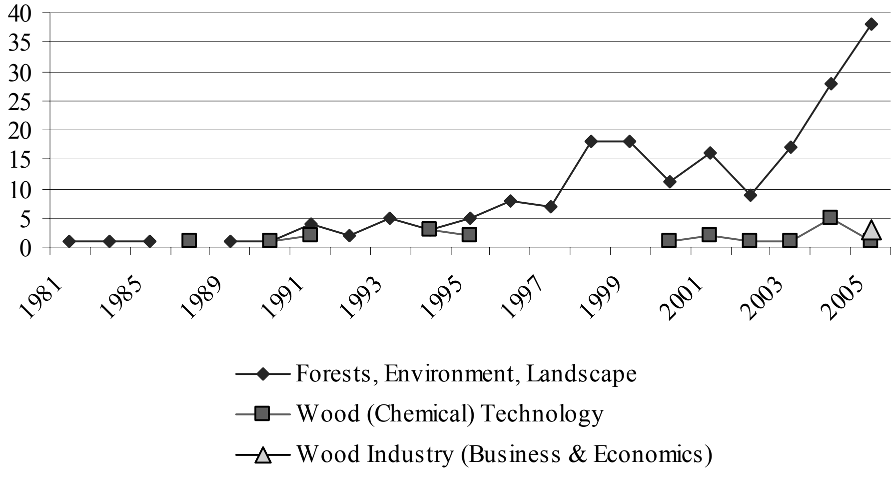

Figure 12. The Number of Publications by Estonian Authors Cited on the ISI Web of Knowledge (Authors' calculations)

64 The comparison rests on European Communities and Eurostat, *Education across Europe*, (Luxembourg: Office for Official Publications of the EC, 2003).

65 There is anecdotal evidence, that as today, this project has failed and therefore this opportunity has been discussed as something theoretically possible rather than applied in practice by wood sector firms.

The Finnish situation is considerably different, there are about six universities with several related departments and additionally about ten research institutes or departments of institutes specializing in wood sector fields (EFI, 2006). Many of the research institutes make an impact above the world average in wood-related science fields (Husso et al. 2000) or represent even more than 25% from the field's total publication output (European Commission, 2003).

As shown in previous sections, the main source for innovation is found to be internal resources in wood sector companies. Stemming from the continuously increasing need for skilled workers, as reported to the European Parliament (2000), the skilled labour shortage could become the main impediment and threat for the competitiveness of wood industries around the EU in the future. There are many issues underlining this development – as the higher need for skills makes recruitment more difficult for companies around Europe, intensive competition in wood markets is aggravating the potential to pay higher wages. The idea that blue-collar education is not generally satisfactory in Estonia is supported by interviews with wood sector managers. The skills of employees (especially those of factory workers) were even stressed in an interview with one of the managers as the main impediment to rapid technological upgrading (Kukk, 2003).

As can be concluded from the above review, Estonian public R&D specialisation does not correspond with the specialisation of industry in the case of the wood sector. Public policy supporting industry-academia linkages is missing, but also, even more importantly, maintaining and securing the existence of respective educational and science institutions has not been prioritised.

2.3.3. Simulation of innovation policy impacts on the basis of the Estonian wood sector

In sections 2.2.2 and 2.2.3, knowledge sources that have contributed to innovations in Estonian wood sector firms were analysed. It has been possible here to analyse only ex post decisions concerning the choice of the innovation sources that have successfully led to an innovation (thereby several types of product and process innovations were considered). As several information sources are used by companies simultaneously in different combinations, the purpose in this section is to analyse the respective knowledge flows that can be encouraged by public policy (e.g. supporting cooperation with universities, consultants, competitors etc.) that complement and enhance (or discourage) the innovative processes of firms.

For the policy analysis, the models developed in section 2.2.2 are further used to predict how the likelihood innovation would change, if some policy measures increased the use of a particular knowledge source. For this, the sample enumeration method is used to calculate the aggregate probabilities of conducting certain types of innovations[66]. The relative strengths of this method in comparison with other methods are discussed by Ben-Akiva and Lerman (1985:146–153). The predicted share of the sample choosing alternative i (which is a respective type of innovation; $\hat{W}(i)$) is used as an estimate for the real share of choosing alternative i; $W(i)$: $\hat{W}(i) = \frac{1}{N}\sum_{n=1}^{N} P(i|x_n)$, where N is the number of firms in the sample (Ibid., p. 146).

The intensity of knowledge sources is simulated according to the policy areas brought out in section 2.3.1.

1. Networking promotion. More keen knowledge exchange with all types of business partners would have positive results for innovation; however, here competitor collaboration (which can be more informal between firms, but more formal through industry associations) is selected for analysis. For the simulation, the knowledge exchange from these sources of knowledge is increased in the first strategy in firms, who have pursued continuous R&D activities (considered to be more likely engaged, but also more capable for new innovation cooperations) and in the second strategy also in firms with occasional R&D activities. The two strategies would imply less intensive and more intensive strategies for public support. To simulate the results, the knowledge exchange is set to increase by one category of interaction in these firms (from not used to used with low relevance to innovation, from low relevance to medium and from medium to high relevance, thereby leaving the high relevance unchanged).
2. Developing a local supply of expertise was seen through advancing knowledge interaction with universities, but also through increased use of internal knowledge sources, which would be the result of a better supply of specific human capital.
3. Supporting and concentrating innovation related services was invisaged through increasing the use of consultants, but also of visits to conferences and fairs.

The results are summarised in Table 57. From the table, we can see the estimated probabilities of different innovation activities and the impact of public policy on them. As can be seen, knowledge management innovations are best targeted by increasing knowledge interactions with universities, but even more with consultants, whereby competitor collaboration and use of conferences

[66] Here, the individual probabilities are studied instead of odds ratios or marginal effects, because the purpose of the analysis is to predict an event – choosing a public sector research institution or university as a knowledge source (of different intensity) and not to estimate the size of a single parameter.

leaves this type of innovation unchanged. Relational innovations can only be enhanced by supporting the use of the respective consultants.

Table 57. Estimated and simulated average probabilities to innovate across types of innovations

Types of innovations	Estimated probabilities	Universities		Competitors		Consultants		Conferences	
		I	II	I	II	I	II	I	II
Knowledge management innovations	0.25	0.26	0.27	0.25	0.25	0.27	0.29	0.25	0.25
Relational innovations	0.26	0.26	0.26	0.26	0.26	0.29	0.30	0.26	0.26
Product innovations	0.52	0.54	0.53	0.54	0.55	0.52	0.52	0.54	0.54
Service innovations	0.09	0.10	0.12	0.07	0.00	0.09	0.09	0.09	0.09
Design innovations	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Process innovations	0.46	0.39	0.37	0.46	0.46	0.48	0.50	0.48	0.49
Auxiliary process innovations	0.28	0.26	0.25	0.28	0.28	0.28	0.28	0.28	0.28
Work organisation innovations	0.39	0.43	0.46	0.36	0.34	0.41	0.42	0.39	0.39
Logistics innovations	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.46	0.48
Marketing innovations	0.19	0.19	0.19	0.21	0.23	0.19	0.19	0.19	0.19

Product innovation can be enhanced through competitor collaboration and use of conferences; however, service innovation can be increased through supporting universities. Design innovation cannot be enhanced by the public policy described by these models. From among wood sector companies those that mostly depend on design include Estonian furniture firms, who are generally reactive to the design setting of competitors – they seldom initiate new design trends (Mollerup Designlab, 2003). Only 20 firms in the furniture industry employ designers, and among these 5 companies are exporters. All of these companies are micro companies on the basis of their employment (Ibid, p. 9). There is unfortunately no information about externally purchased design services, but since most of the R&D is internal[67] for furniture companies, it can be assumed that external design services are rarely used. The barriers to incorporating design activities in furniture companies mainly relate to the lack of designer knowledge in consumer tastes in target markets[68], high costs and

[67] According to the calculations based on the Electronic Database of the Statistical Office of Estonia, the share of external costs of R&D has been 4–7% in 2003–2004.

[68] It has been noted that Estonian furniture designers are capable of designing award winning furniture that is very highly-credited by design communities, but these

risks associated with those activities, but also the concentration of designers in the capital city (Ibid, p. 51–55). There is a certain role in public policy to remedy this situation; however, this cannot be captured by the groups analysed here.

Technological process innovations are best enhanced through the intensified use of consultant services and conferences. Experiences with universities has been so negative[69] that several managers don't even know what issues they could cooperate on because the universities are considered so outdated with regards to their knowledge of new technologies [6]. The knowledge offered by the universities is either not firm-specific enough or there are no universities in the country that possess competences in the right field [6,7,9]. The managers who have more experience on the Finnish market, feel that from the scientific perspective, one should rely more on specialised science parks and competence centres to support innovation in the wood sector, especially concerning the application of advanced technologies for wood sector innovations [1]. Some managers communicate with scientists in more informal ways to exchange information, larger wood industry associations have scientists as well as representatives from vocational schools on their committees. Only a couple of managers have delivered lectures in universities [5]. Only two managers mentioned a master's project supervised jointly with the university so the manager dealt with the firm-specific problems [10,12].

One field associated with the wood sector that joined private and public funding via Enterprise Estonia and involved cooperation between industry and academia – is establishing testing and certification labs. Several firms from different sub-industries described such attempts as not successful [2,4,19]. The reasons mentioned for their failure were the low motivation or lack of staff on behalf of the university, but also the slowness of the processes of certification and lack of interest in the certificates on behalf of the consumers or distributors in many sub-sectors [2,4]. In some narrow segments for example, where the leading firm on the world market (who possesses the only certificate in the branch) also leads the certification process, this kind of certification has become one of the barriers for newcomers entering the market, but also makes it difficult for SMEs to operate. It can be concluded that cooperation with educational institutions has a lot of room for improvement in order to make a valuable contribution to innovation processes in firms.

Logistics innovations have been best enhanced by enhancing the use of conferences as sources of knowledge and marketing innovation through compe-

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furniture designs are not commercially successful on the export markets (Mollerup Designlab, 2003: 53).

69 In several equations, the universities had quite large negative coefficients; therefore their increased use decreased the probabilities even despite the positive effect of improved use of internal sources.

titor collaboration (which has actually been seen in practice in of the log-house industry – the German export market was re-opened thanks to the joint efforts of competitors via the industry association). Although this is a rare example [2], the positive potential is clear.

The results show, that so far universities are only contributing positively to one type of innovation (innovation in work organisation), and which is consistent with the interview results – a few cooperative projects with universities in supporting fields outside the core-technological activities were identified (for example, waste management, training projects in some very specific fields etc.) [6,10].

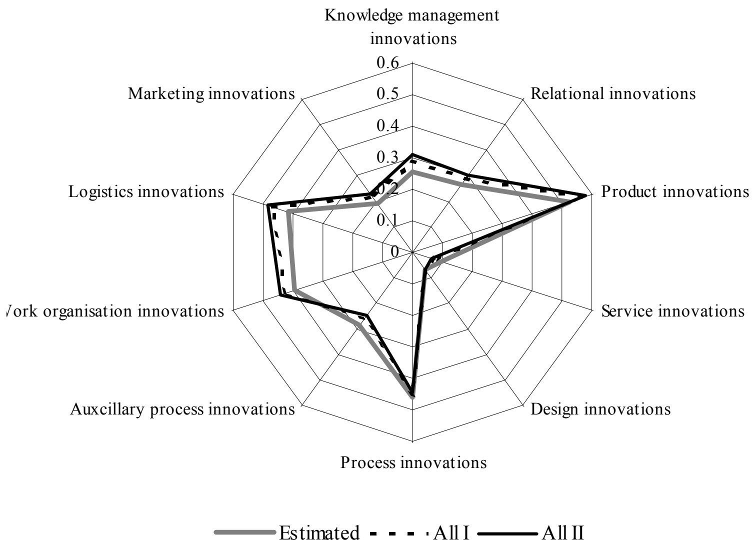

Figure 13. The impact of joint policy simulation on average innovation probabilities

From the analysis, it is evident that the strengthening universities is currently enhancing work organisation innovations; encouraging industry associations and competitor collaboration is increasing the chances for marketing innovations; supporting the use of consultants is increasing knowledge management and relational innovations and supporting the use of conferences is improving innovativeness in logistics (see also Figures 1–4 in Appendix 28).

By looking at the joint impact of measures analysed, as revealed in Figure 13, only soft innovations are being encouraged, technological innovations seem not to depend on these kinds of measures (because they are associated with business network partners such as suppliers and customers). This however, can also have an indirect effect on technological innovations. Besides, the soft innovations (e.g. marketing, logistics, knowledge management) are certainly very important if the creation of value added in the industry is considered.

This kind of methodology has several drawbacks. It is merely the analysis of the co-existence of relationships, so the causes and effects are mixed in the results. The simulated values are imputed by holding everything else not changed, which is very unlikely to happen in reality, where the dynamic learning environments would change the existing relationships. Additionally, the method of increasing knowledge interaction in those firms with more than average capabilities is also causing a shift in the potential to innovate in more capable firms thereby leaving the less capable untouched (see also changes in individual probabilities in Figures 1–8 in Appendix 29), but there is also a chance for those to advance through encouraging policy means.

There are also purely technical problems associated with the small sample size on the one hand and the low explanatory and prediction power of some equations on the other. There is no way of trying to consider these factors and their future changes, which are not modelled in the estimations.

Bearing in mind all of the shortcomings of this study, the results nevertheless highlight the importance of the responsiveness of the national innovation systems to the industrial specialisation of the country. The comparison of Estonian and Finnish wood sectors reveals that the Estonian public R&D base is not aligned to the sectors under discussion. This result is in line with other, more general studies of the Estonian national innovation system stressing its 'high-tech' orientation. In Finland, on the contrary, public policy has facilitated R&D cooperation in the public and private sector via cluster-programs especially in fields where the respective economic specialisation has indicated competitive advantages.

While the absorptive capacities of firms in Estonian wood sectors are rising, the lack of respective domestic research institutions could become an impediment for the development of the whole wood sector in the future. Judging by these results, one can therefore foresee a decisive role for the Estonian government, but also for industrial associations in improving knowledge creation and dissemination in the wood sector in Estonia. The government's role is seen mainly in improving the inefficiencies in the structure of the Estonian education system and creating wood-related industrial research and development competence. Industrial associations face the task of encouraging closer liaisons between industries and educational and research institutions, and promoting the positive image of forestry and wood professions, but also to encourage competitor collaboration.

The future development of the Estonian forest and wood cluster should be oriented towards the development of high–end production capacities in the value network. This requires the joint efforts of the government and industry, as well as collaboration–oriented behaviour among Estonian companies.

CONCLUSIONS AND DISCUSSION

This research has explored the knowledge used for innovation using Estonian wood sector firms as an example of a traditional industry. Theoretical concepts leading to the formulation of a framework for analysing this problem are found to be rooted in the resource-based theory of the firm, which sees firms as knowledge reservoirs, and in evolutionary economics, which sees innovation as an outcome of (path-dependent) knowledge production and use.

There is not much literature dealing systematically with the content, characteristics and sources of knowledge used for innovation. The review of the literature in Section 1.1 described the variety of types and categories of knowledge firms use in their innovation processes. The available empirical studies (Gibbons, Johnston, 1974; Faulkner et al., 1995 and Vincenti, 1991) show that each type of knowledge is obtained mainly from a specific source. The business organization literature and specific innovation studies analysed in Section 1.2 find different determinants of the choices of knowledge sources important. These are mainly industry or sectoral determinants – source-specific factors (e.g. meaning the strength of the knowledge base of a specific source – public sector research, suppliers etc.), innovation type or technology-related factors and firm-level factors (size of the firm, the background of the manager etc.) were found to be relevant.

By synthesising the specific sources and categories of knowledge, the following conclusions can be made. Internal sources of the firm are a dominant source of knowledge used in the innovation processes mainly on the basis of core innovation activities. Within the internal category of knowledge, the personal knowledge of the problem-solver is more relevant in most categories of knowledge used in innovation (except for properties of components, materials and theories, and laws).

External sources are more relevant in categories of knowledge related to knowledge (existence of special facilities etc, location of information). In this way, business partners (suppliers, customers, consultants) as sources of knowledge dominate only in the category of research equipment. It is a shortcoming of several studies that competitors as sources of knowledge are not studied; however, as Vincenti's study shows, their role is relevant in transferring more practical or tacit knowledge about specific problem solving issues. Public sector research dominates in following innovation activities: scanning the research frontier and underpinning knowledge. Hence, the intensity of formal contacts varies across sectors, but informal interaction is widespread in all sectors.

Sectoral differences are mostly found in the different relative importance of internal sources compared to external sources, but also in the relative intensity of the use of business vs. public sector research as knowledge sources.

In addition to sectoral differences, types of innovation stemming from different technologies are also relevant; for example, suppliers or consumers as external sources of knowledge are relevant when considering process or product innovation, respectively. However, in the empirical results, some interesting complementarities can be found – suppliers and literature as external sources are relevant across different types of problem-solving; in addition, personal sources and literature are similarly relevant at the same time in many categories.

The specifics of wood-related sectors is mainly revealed in the close relationship between product and process innovation, the importance of architectural capabilities in firms and the relevance of technological gatekeepers within the firm. Therefore, the internal sources (in the form of personal sources for instance, in the case of gatekeepers, but also with regard to shop-floor workers) are relevant. However, as tacit knowledge is more relevant for the type of technologies this sector is using, this is obtained in great part from external in addition to internal sources. From among external sources, suppliers, but also customers and competitors are used. The importance of the public R&D institutions and universities lies in technological, R&D and testing skills and equipment, but also seems to be associated more with public R&D specialisation.

In the research, nine hypotheses were constructed. The first group of hypotheses concern the role of different knowledge sources in the innovation processes (H1, H3, H4); then factors influencing different sources of knowledge were explored in the second group (H2, H5–H7). Finally, the complementarity and sustainability issues of knowledge sources were proposed in H8 and H9.

The research data and methodology were chosen according to the research problem, but also by using the available datasets. In order to carry out an econometric analysis, the Community Innovation Survey databases covering 1998–2000 and 2002–2004 have been used. In order to include broader background factors in the analysis, interviews with industry managers were conducted in 2006. The interviews are used to help in selecting the final set of hypotheses relevant for Estonian wood sector firms. Fin the econometric research, the logistic regression technique was applied following the type of data and the research problem (discrete choice) analysed; in addition, the univariate analysis of variance is used to compare the means of intensity of different sources. As the empirical part primarily rests on the analysis of logistic regressions, some comparative statistics are also used to describe the general background of the industry and to compare the Estonian wood sector with the Finnish wood sector. To arrive at policy recommendations, a simulation exercise was executed and the results drawn together using a sample enumeration technique.

The results from CIS3 and CIS4 data show that wood sector firms have responded to changed competitiveness conditions in export markets, but also to increased labour cost pressure in the domestic market with intensified innovative activities and increased investments in new technologies. The strongest remaining barriers to innovation are the lack of internal finances and the lack of competent personnel, but also the high innovation costs that are felt more compared to other manufacturing industries.

The overall intensity of knowledge use was identified to be lower regarding most innovation sources compared to the Finnish forest and wood cluster. Internal innovation sources predominate with similar intensity in the wood sectors in both countries. From among external sources, suppliers, customers and also competitors are important. As could be expected, the use of R&D institutions and universities as information sources was low on the one hand presumably because of the low absorptive capacity of the firms, and on the other because of shortcomings in the research in Estonian universities in this field, and hence, weak potential for science-industry bridging in such low-tech sectors. Suppliers are the most significant partner for innovation cooperation and also the second innovation source after internal sources. Innovative activities mainly result from knowledge production or acquiring knowledge from external sources rather than from pure expenditure on external knowledge acquisition. As was found by most of the empirical models tested in this research, the processes of innovation are sector specific.

Table 58. The validity of the hypotheses tested

No.	Content	Result
H1	Internal sources of the firm are the main sources of knowledge used for innovation processes	Supported in most important innovations, in others – mixed results
H2	The firms with stronger internal capabilities more likely use different kinds of external knowledge sources	Supported in most important innovations, in others – mixed results
H3	Customers are used to obtain knowledge for product innovations	Supported
H4	Suppliers are a source of knowledge for technological process innovation	Supported
H5	Concern members use competitors as knowledge sources less for innovation	Supported in 1998–2000, not supported in 2002–2004
H6	Financing barriers to innovation discourage the use of external knowledge sources	Supported
H7	Knowledge-related barriers to innovation encourage the use of external knowledge sources	Supported
H8	External knowledge sources complement the firm's internal knowledge sources	Supported
H9	External knowledge sources complement the use of other external knowledge sources	Supported in most important external sources, others – mixed results

However, one can make several conclusions based on the empirical results of testing these hypotheses (see also Table 58). By looking at the general pattern of knowledge flows, this reflects the dominance of suppliers in innovation processes, which is consistent with the taxonomy presented by Pavitt (1984). Contrary to the literature, we find that suppliers are used only for process innovation (not product) and customers are used for product (but not for process) innovation (see also Table 58).

Suppliers contribute knowledge to each part of the innovation chain, but more intensively to production and design processes. The importance of customers (although similarly highly assessed) was found to concern only product innovation activities. Conferences are used for several stages – design, production and distribution activities; and competitors, for design and distribution activities. There are some country-specific factors (transitional education and science system) found to be relevant because the R&D institutes were not able to contribute to any single stage, and universities only to work organisation. Therefore, in the following section, the factors that underlie the choices of innovation sources are discussed to better understand the situation.

From the analysis of the factors behind the choices of knowledge sources, there are many in line with earlier empirical research; however, some sectoral specificities can also been seen. Internal sources are more relevant for innovation in larger firms and in firms with some internal R&D activities; R&D activities also encourage firms to use external knowledge sources (absorptive capacity argument). Suppliers and customers are used respectively for process and product innovations and by firms lacking technological or market knowledge, respectively. These patterns are clear in the wood sector, and this differs from the evidence in the literature according to what in some other sectors customers contribute to process and supplier to product innovations.

Competitors and industry associations are used for several types of cooperative innovation projects and firms that are members of a concern are becoming more and more embedded in local networks (see Table 58). Consulting firms are used in addition to consumers to obtain market-related information, but here formal cooperation causes the firms to recognise the financial barriers.

The public sector research base, in contrast to the literature, is used for market-related knowledge, which might be a result of the unresponsive public R&D specialisation in respect to the needs of the wood sector.

In summarizing the results for the complementarity issue, complementarity between internal and external knowledge sources seems evident. At the same time, most of the external sources also seem to complement each other. There are interesting exceptions found in some external knowledge sources. In the case of public sources – R&D institutes, universities, consultants and conferences – there seems to be substitutability in use for innovation activities. This means on the one hand, that those sources offer similar knowledge to firms, but on the other hand, this result is certainly valid only in the case of the

Estonian wood sector. The reason for this lies in the public sector's inability to offer knowledge that contributes to the knowledge of firms in the field of testing, novel research equipment and so on, and therefore the firms obtain a consultancy service about the markets rather than the technological help they could really use.

Policy implications

In this research, the systems approach to innovation was used to analyse innovation in industries related to wood and wood products. The sectoral systems approach to innovation embraces the whole value network of the respective production with all the underlying relationships between different actors relevant for that sector. In general terms, the results of the research coincide with the sector-specific use of innovation sources found by earlier research.

The research conducted shows that core innovation processes (product and technological process innovation) for the wood sector are currently primarily embedded in business networks. Public sector actors are only participating in soft innovations and mostly in an extremely weak manner. Given the fact that the success of the sectors has primarily been in technological development and not so much in advances within the value chain, besides generally supporting networking for innovation, the public sector's role in this sectoral innovation system needs to be addressed. In addition, according to the leading firms, as the technological base achieves an international standard, it also becomes crucial how the firms will start to develop and advance the technologies in use. They might be seriously constrained by the lack of theoretical knowledge, testing facilities etc.

The analysis also showed strong complementarity between knowledge sources. This result has an important policy implication for developing a sectoral innovation system. Firstly, it indicates the irreplaceability of different types of players in the innovation system (one cannot rely on supporting some actors while ignoring others); and second, in the case of the under-development of some actors, others try to fill these gaps, but with a lower success (because the knowledge corresponds to their core competences).

Future research

Future research into knowledge used for innovation has to address the following points. First, a more specific empirical sectoral analysis has to be carried out in detailed knowledge categories to improve the state of the art in this field. Concerning the traditional industries, it would improve our understanding of how traditional sectors are linked to high-tech sectors, but also to understand better what policies should be used to contribute to these processes. The complementarity issue and factors behind it have hardly been tackled in the literature, so this is also a research gap for future studies analysing how to achieve the synergetic use of complementary knowledge sources.

In addition, some cross-country studies of similar industries could be carried out, because the institutional constraints on the exchange of knowledge have to be analysed on the basis of more detailed knowledge categories. The question of how to align private and public sector innovation-related interests would be essential to the development of the competitiveness of such traditional industries.

From the specific research questions raised in this study, it would also be worth take a more in-depth look at questions related to the internal and concern-based linkages with the coordination of innovation, but also issues on how these encourage or lock-in innovation processes on the international level.

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APPENDICES

Appendix 1. General categorisations of knowledge used in innovation

Authors	**Categories of Knowledge, Skills, Experience**	**Role in Innovation Processes**	**Sources**[70]
Polanyi (1966) Nelson, Winter (1982) Winter (1987) Dosi (1988)	Tacit (implicit) vs explicit Teachable vs nonteachable Articulate vs nonarticulate System-quality vs stand alone Nonobservable in use vs observable in use Complex vs simple Specific vs general	The categories express the ease of knowledge transfer between the firms/individuals and access to knowledge (the right side categories represent the more easy transfer). These categories interact in an evolutionary way within the routines of an organisation (the choices of individuals are selected in or out in accordance to the utility gained and in interaction with the external economic environment and then stored in routines) (Nelson, Winter, 1982).	Personal (experience) on left hand categories, Personal (education) on right hand categories Both types via different channels from internal sources and external sources, but the categories on the right side are more easily stransferred.
Fleck, Tierney (1991)	Metaknowledge	General cultural and philosophical assumptions. In relation to the technological innovation can be regarded as technocratic rationality (seen as 'objective', 'ungendered', 'apolitical' and so one).	Personal (education, experience).
	Milieu	Local work environment, relations to peer groups, management and other staff. Related to how work is organised and division of a labour is achieved within the firm, how the power dimensions of the 'milieu' are related to its knowledge categories. For example, if a given innovation makes use of certain technological resources, then any firm, that either does not have people who can command and perceive the importance of those resources or doesn't provide the working environment in which they can be appropriately deployed, will be excluded from the possibility to produce that innovation.	Internal sources, local networks

[70] In studies, the sources are a somewhat differently defined.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
	Contingent knowledge	Distributed and apparently trivial information, specific to the particular environment and its contents. Similar to on-the-spot learning.	Everybody holds contingent know-ledge, but depending on the structures and relations of power within and between the organisation, not everyone's contin-gent knowledge is equally recognised, solicited, valued or acted on. Internal and personal sources.
	Tacit knowledge	Rooted in practice and experience. How particular people do (or do not) gain access to particular forms of knowledge creation and exchange.	Transmitted by apprenticeship and training.
	Informal knowledge	Rules of thumb, tricks of the trade and so on.	Available in verbal and sometimes written forms, eg. guidebooks and manuals. Internal sources and experiments.
	Formal knowledge	Theories and formulae. Points for example, to the potential exclusion of non-graduates from acquiring certain forms of knowledge or for example, on the construction of standardised 'ways of seeing' through the use of formally explicated design methodologies.	Available usually in written form such as textbooks and handbooks.
	Instrumentalities	Knowledge embodied in tools and instruments (de Solla Price (1984) argues that advances in instrumentalities have been with major importance for radical advances in fundamental science, but also radical innovations in practical application). They require other components – informal, tacit and contingent- for effective mobilisation.	Suppliers. Universities, public R&D institutes.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
Ryle (1949), Lundvall, Johnson 1994)	Know what	The knowledge of facts (mostly in the form of information).	Education (personal, internal sources), external sources (databases)
	Know why	Knowledge about principles and laws in nature, human mind and in society. This kind of knowledge is very important for technological development of certain science-based areas (e.g. chemical and electrical/electronic industries). Access to this type of knowledge would accelerate the advances in technology and reduce the frequency of errors in processes (Lundvall, 2004).	Education, experience (personal, internal sources), external sources: academic community, journals.
	Know how	Skills, knowledge about how to perform certain activities, important for all kind of economic activities. It is misleading to characterise this type of knowledge as practical rather than theoretical, because it is experience-based and can apply for practical as well as theoretical problem-solving (Lundvall, 2004).	Held within the firm or research team (personal, internal sources), can be obtained through cooperation with other firms, but also research laboratories, engaging experts, consultants (external sources).
	Know who	Information about who knows what and who knows what to do, but also the social abilities to co-operate and communicate with different kinds of people (Lundvall, 2004). This type of knowledge is becoming increasinglyimportant because the innovative activities are using more and more complex knowledge from different disciplines.	Personal, internal sources, networking.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
Vincenti (1990: 197–199)	Descriptive knowledge	Descriptive knowledge describes things (devices, technologies) as they are. This is the knowledge of the fact or actuality and it is judged in terms of veracity or correctedness. This knowledge is same for all firms, cannot be altered by the engineers or problem-solvers.	Sources: experimental development, education.
	Prescriptive knowledge	Prescriptive knowledge prescribes how things (devices technologies) should be to attain the desired end). This is the knowledge of procedure or practice and this is judged in terms of effectiveness, of degree of success or failure. Knowledge that is firm-specific and can be altered at will to be more or less effective under financial and other constraints.	However, industrial standards are one example of prescriptive knowledge common to the industry.

Sources: Fleck, Tierney, 1991; Winter, 1987; Dosi, 1988.

Appendix 2. Detailed categorizations of knowledge used in innovation

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources[71]
Gibbons, Johnston (1974: 226) The categories were developed from Myers and Marquis (1969: 81–82)	Properties, composition, characteristics of materials and components	Information describing make-up and performance of both natural and man-made objects useful to include in the new products. Most frequently used category of knowledge in innovation (32.5% of units).	Largest intensity of all sources, mainly from internal (analysis and experimentation), but also external, less personal. From external sources, scientific and trade literature are most important. 20.1% personal, 49.3 internal, 30.6% external sources.
	Existence or availability of equipment and materials with particular properties	Knowledge that is useful to include in the new product (13.9% of units)	Mainly external sources, from internal sources, personal are more important. From the external sources, literature (trade literature and hand- and textbooks), but also suppliers and customers are more frequently used. 38.2% personal, 8.9% internal, 52.8% external sources.
	Design-based information	Information resulting from analysis of the required or appropriate design, such as particular performance characteristics or necessary materials (13.9% of units)	Mainly from internal sources, personal and other internal sources relatively equally important. From external sources, literature generally and suppliers are used more frequently. 40.7% personal, 32.5% internal, 26.8% external sources.
	Test procedures and techniques	Analysis and testing for any particular type of performance of new product or process (10% of units)	Internal and external sources are with similar importance; however, personal knowledge is more important. From external sources literature (especially hand- and textbooks) is important. 50.6% personal, 19.1% internal, 30.3% external.

71 In studies, the sources are a somewhat differently defined. In Gibbons and Johnston (1974:225), the source is the one from which the problem-solver directly obtained the information, and not the original producer of the information. They distinguish the sources of the problem-solver in following way: internal sources -- personal sources (meaning the problem-solvers knowledge that has been developed by the education and experience), sources within the firm and sources external to the firm. In current study, the internal sources are considered to be both, personal and within the firm, external sources refer to the sources outside the firm.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
	Operating principles or rules, required specifications, technical limitations	Including 'rules of thumb', properties of materials relating to the limit of their performance and technical limitations imposed by standards or customer demand (9.9% of units)	Mainly from internal sources to the firm, personal knowledge more important. From external sources, literature is relevant. 52.3% personal, 33% internal, 14.8% external.
	Location of information	Information about where particular information may be found, including either reference to literature or to a particular person or organisation (8.8% of units)	Mainly from internal sources to the firm, personal knowledge more important. From external sources, universities and suppliers are important. 64.1% personal, 10.3% internal, 25.6% external.
	Theories, laws, general principles	Not only of a scientific nature, but also more general technical principles (8.0% of units)	Mainly from external sources. Scientific literature and universities are most frequently used. 28.2% personal, 22.5% internal, 49.3% external.
	Existence of specialist facilities or services	Information describing the existence or location of specialist facilities services such as analytical services, sophisticated instrumentation or even library facilities. (3.0% of units)	Mainly from external sources. Universities and suppliers are used more frequently. 14.8% personal, 14.8% internal, 70.4% external.
Vincenti (1990: 208–240)	**Fundamental design concepts** The principles that are making a particular artifact work ("operational principles" of Polanyi (1962)) and The normal configuration of a device (the general shape and arrangement that is commonly agreed to best embody the operational principle). These two make up a normal technology or design of a device. In addition, this is also principle that provides a criterion by which the success or failure is judged in technical sense.	Incremental innovation can be understood as the improvement normal technology or its application in new conditions. Radical (revolutionary) innovation (radical design/ technology called by Vincenti) involves a change in normal configuration and possibly also in operational principle. In latter event the configuration must be only established, because it cannot be known at the outset.	Invention Theoretical engineering research Experimental engineering research Direct trials (including operation) in both, production and by customers. Design practice has more indirect nfluence. This category of knowledge is obtained from engineering education or experience (internal and personal sources). From external sources, customers or social groups are most influential.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
	Criteria and specifications The general qualitative goals of the device or technology are translated into the specific quantitative, concrete technical terms. In more general circumstances, these technical specifications can apply across an entire technology.	The problem must be well defined for contriving the details and dimensions and therefore the universal specifications can be seen as the stored-up body of knowledge about how things are done. In any innovation project this is the knowledge needed for devising relevant criteria and specifications.	Theoretical engineering research Experimental engineering research Design practice Direct trials (including operation) Personal knowledge of technical criteria appropriate to the device and it's use, but also limitations are needed, general engineering education, experience in the specific device. From external sources, users are most relevant.
	Theoretical tools Mathematical methods and theories, meaning the body of mathematically structured theoretical knowledge useful for quantitative analysis and design (engineering theories, but also phenomenological theories involving some central ad hoc assumption of the phenomena central to the problem). Intellectual concepts needed for conceiving and analysing artifacts.	When limited to specific devises, these theories are describing the mathematical feasibility on some approximation specific to a device. Intellectual concepts are needed for qualitative conceptualising and reasoning before the quantitative activities are started.	Transfer from science Theoretical engineering research Experimental engineering research Direct trials (including operation) Design practice has more indirect influence. Personal education. Literature: hand- and textbooks, professional journals, government publications, proprietary company reports; but also memories of individuals.
	Quantitative data Data may be derived theoretically or empirically (usually empirically) or may be prescriptive knowledge or descriptive knowledge.	Used in above–described tools and specifications for designing a device.	Original sources: Transfer from science Theoretical engineering research Experimental engineering research Production Direct trials (including operation) Design practice has more indirect influence. Literature: hand- and textbooks, professional journals, government publications, proprietary company reports; but also memories of individuals.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
	Practical considerations Considerations that are derived from practice and are not codifiable (sometimes more or less unconscious to the engineer or designer), rules of thumb. In the longer run in case they become precise enough, some of them may be codified (and move to the category of quantitative data).	Practical experience and rules of thumb allowing for rapid assessments and judgements in the process of designing a device.	Design practice Production Direct trials (including operation) Learned on the job, based on experience. Feedback from the use is essential.
	Design instrumentalities Procedural knowledge or knowing how to carry out the tasks. (structured procedures, ways of thinking, judgemental skills).	Procedures, ways of thinking, judgmental skills required in the process of designing a device, but also seeking the solutions where some degree of novelty is required. Procedures of satisficing are less formal and demand for more judgmental skills than optimising. However, engineering problem-solving is more of satisficing kind.	Theoretical engineering research Experimental engineering research Design practice Production Direct trials (including operation) Judgmental skills (visual thinking, call for insight, imagination, intuition, feeling for elegance and aesthetics in technical design) – mostly tacit skills. Learned in practical experience. Those skills are more personal, although they are shared to some extent between designers.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
Faulkner, Senker, Velho (1995); Faulkner (1994)	*Related to the natural world*		
	Scientific and engineering theory ("laws" of nature; theoretical tools)	Used in engineering experimentation of new products and processes	Science (universities), technology (internal, public sector R&D institutions)
	Properties of materials (natural and artificial materials)	Properties of artifacts and of nature used in product and process innovation	
	Related to design practice		
	Design criteria and applications (understanding of user requirements; demands of company and technology; specifications of components)	[72]Design criteria are drawn up on the basis of the dual requirements of companies and potential users. Detailed specifications are produced by following more technical considerations, feasibility etc. Alternative concept designs are considered and one is eventually selected, thereafter the detailed design of the product is elaborated.	Internal sources, customers
	Design concepts (fundamental operation principles; normal configurations; creative ideas)	[73]Fundamental operation principles are the basic ones that make a specific artifact work. Normal configurations encompasses the arrangements and shapes commonly taken to be the best embodiments of operating principles. Creative ideas are relevant in both, concept design and detailed design.	This kind of knowledge is rather technological and often taken as for granted, because is absorbed from earlier engineering (internal sources). Rarely emerge in a vacuum, internal resources, but also openness relevant.
	Design instrumentalities*	[74]Encompasses structured procedures; ways of doing things and thinking; handling complex and conflicting design requirements.	Internal sources. Judgmental skills
	Design competence* (general design competence; competence in specific product area)	Considerably overlap with the design instrumentalities.	Internal sources. The role of competences and skills is highly relevant in all aspects of design – general and specific.

72 The stages follow Walsh et al (1992) Chapter 7.
73 The sub-categories follow Vincenti (1991) Chapter 7.
74 Adopted from Vincenti (1991) Chapter 7.

Authors	Categories of Knowledge, Skills, Experience	Role in Innovation Processes	Sources
	Practical experience	Experience in the field (both, user experience of operation and producer experience of production), "rules of thumb" from earlier design experience.	Internal sources (experience in production. Customers (user experience)
	Related to experimental R&D		
	Experimental and test procedures	Accepted ways of setting up experiments and test.	Internal sources, universities, public R&D institutions
	Research instrumentalities* (ability to utilise experimental techniques and equipment; ability to interpret test and experimental results)	[75]Techniques and artifacts used in the course of experimental R&D. The ability to use research instruments effectively. The ability to interpret test results (Senker, Faulkner, 1992).	Internal sources, universities, public R&D institutions
	Research competence* (general research competence; competence in particular specialism)		Internal sources, universities, public R&D institutions
	Experimental and test data	Output of R&D. Related to both, properties of materials and to operating performance.	
	Related to the final product		
	New product ideas	Rarely emerge from a single step, but rather "coalesce" over a period of time.	Internal sources.
	Operating performance (performance of components or materials; pilot production, field trials and so on; user experience)		Knowledge about operating performance comes from pilot production, direct trials, user experience. Knowledge of performance of materials and components comes from suppliers and users, and from experience.
	Production competence* (design requirements for manufacture; competence in pilot production/scale-up)	Contributes to early concept design (ideally) as well as to later detailed design through pilot production.	
	Related to knowledge		
	Knowledge of knowledge (location of particular knowledge; availability of equipment, materials, specialist facilities, or services)	[76]The facility to find out things that are necessary to new product development but are not known to those immediately involved.	Involves search activity and problem solving, external contacts are widely used to locate facilities, literature, and other contacts in particular specialisms.

* Indicates the knowledge in Faulkner et al. (1995) that is heavily skill-based.

75 Follow the categories of de Solla Price (1984).
76 Follows Gibbons, Johnston (1974).

Appendix 3. Comparison of the samples of empirical analyses for categorising knowledge

Study	Time period	Classification/ industry	Distribution of the Sample	
Vincenti (1990)	1900–1950	Aeronautics, design engineering	5 in depth historical case studies involving several firms in the industry over and extended periodof time	
Gibbons, Johnston (1974:224)	1970s	OECD classification (1963:7):	# of firms	%
		High research intensity industries	18	60
		Medium research intensity industries	7	23.3
		Low research intensity industries	5	16.7
Faulkner, Senker, Velho (1995)	1980s and 1990s	Three fields of techno-logy (advanced cera-mics, biotechnology, parallel computing)	66 interviews with R&D staff in 35 UK and US firms	
Fleck, Tierney (1991)	n.a.	Financial services sector	Case studies	

Sources: Vincenti (1999), Gibbons, Johnston (1974:224), Faulkner, Senker, Velho (1995), Fleck, Tierney (1991).

Appendix 4. Intensity of use of different knowledge resources

Study, measured indicator	Intensity of general information use	Intensity of sources
Gibbons, Johnston (1974) Source, from which the problem-solver received this information	887 information units per 30 innovations (29.6 per innovation in average)	34% external 30% internal 36% personal
Rothwell (1977) Source of the original idea for the innovation	n.a.	2/3 in-house R&D 1/3 external sources (mostly other industrial firms, especially users and supp-liers, but also competitors, academic and government sources 5–20%)
Faulkner, Senker, Velho (1995) Impact of knowledge inputs on innovative activities of the firm	n.a., 369 responses	51% internal 27% other firms 22% public sector research

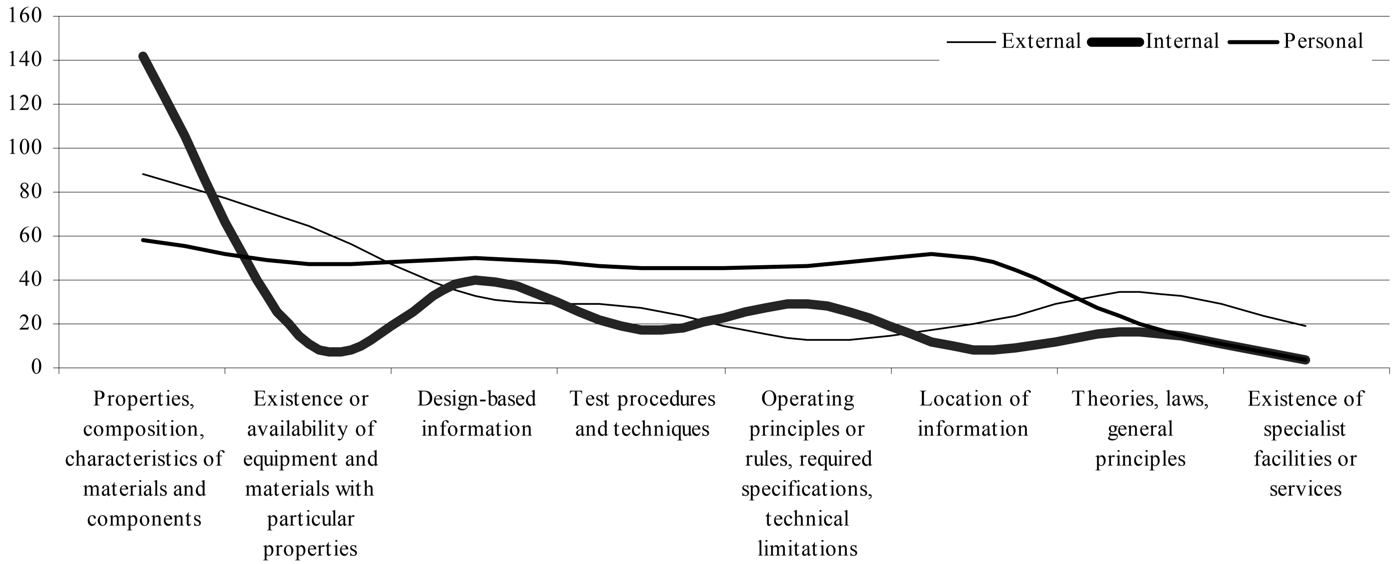
Sources: Gibbons, Johnston (1974:225) Rothwell (1977), Faulkner, et al. (1995:222)

Appendix 5. Broad types and sources of knowledge

	Type of knowledge			
Source of knowledge, Sector	Knowledge	Information	Skills	Artefacts
Internal				
Biotechnology			**TACIT**	**Tacit**
Engineering ceramics			**TACIT**	**TACIT (production) Tacit (research)**
Parallel computing			**TACIT**	**Tacit**
Other companies				
Biotechnology		Formal		**Tacit**
Engineering ceramics		**FORMAL/Tacit**		**Tacit**
Parallel computing		**Formal/tacit**		**Tacit/Formal**
Public sector research				
Biotechnology	**FORMAL**	Formal		Tacit
Engineering ceramics	**FORMAL**			Tacit
Parallel computing	**FORMAL**	FORMAL/Tacit	Tacit	

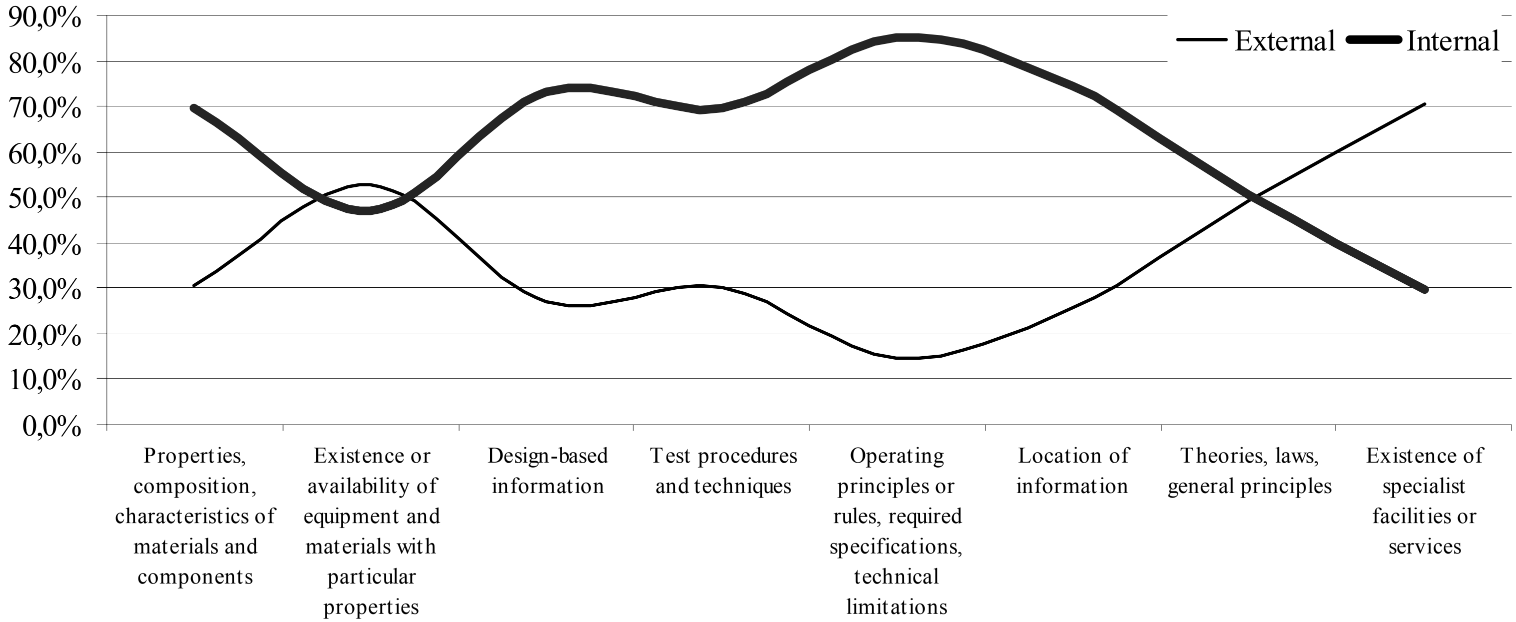
Note: Boldness of typeface indicates the importance of knowledge
Source: Faulkner et al. 1995: 188

Appendix 6. Distribution ofcategories of knowledge used for innovation by units of information



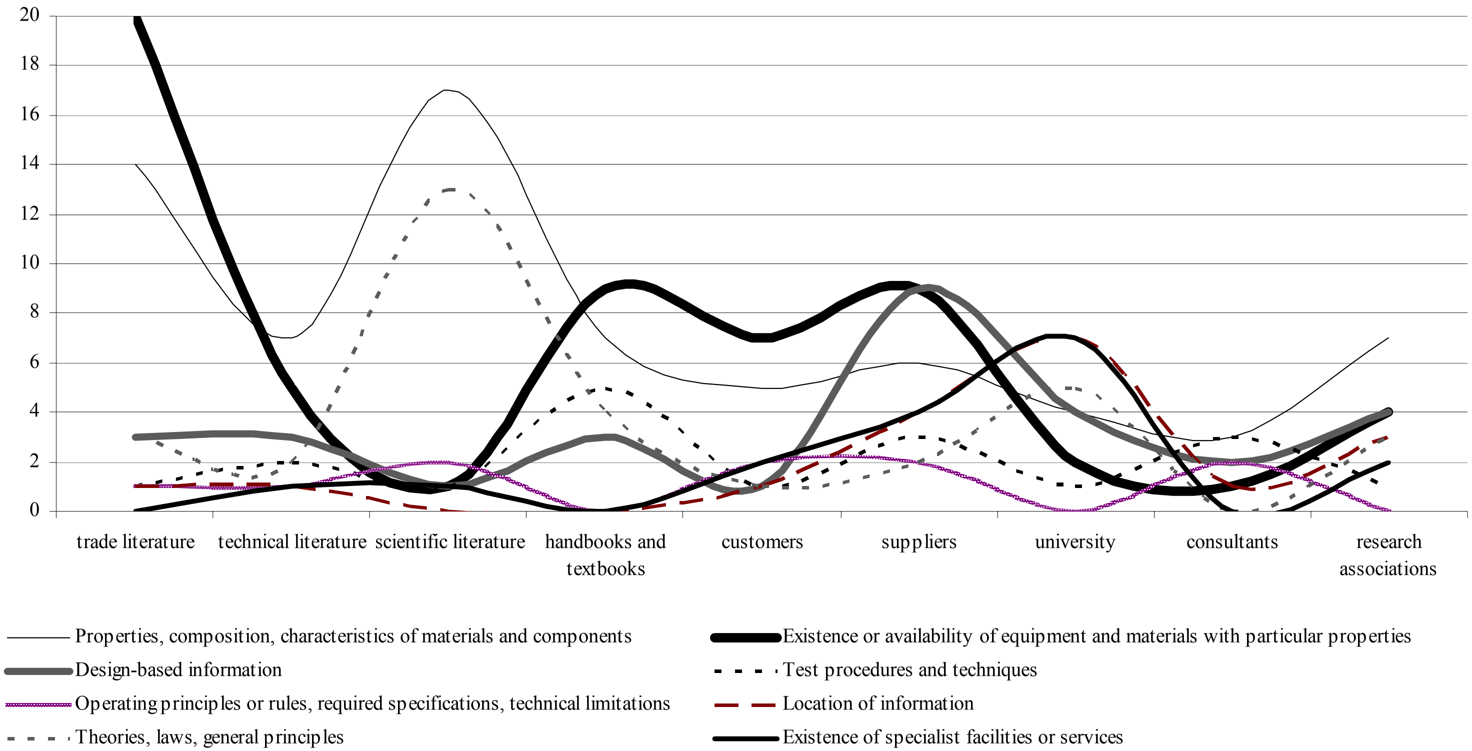
Source: Gibbons, Johnston, 1974

Appendix 7. Distribution of knowledge used for innovation between internal and external sources (%)



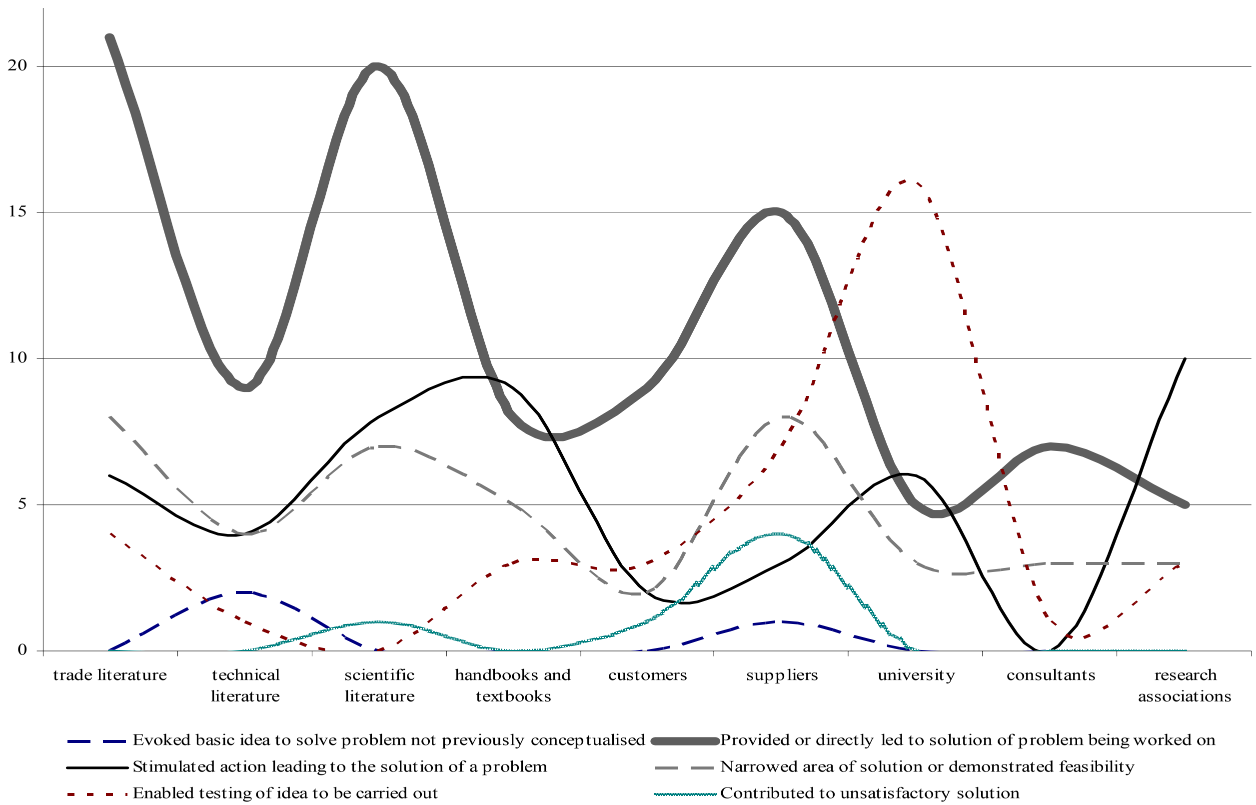
Source: Author’s calculations based on results of Gibbons, Johnson, 1974

Appendix 8. Distribution of categories of knowledge from external sources (units)



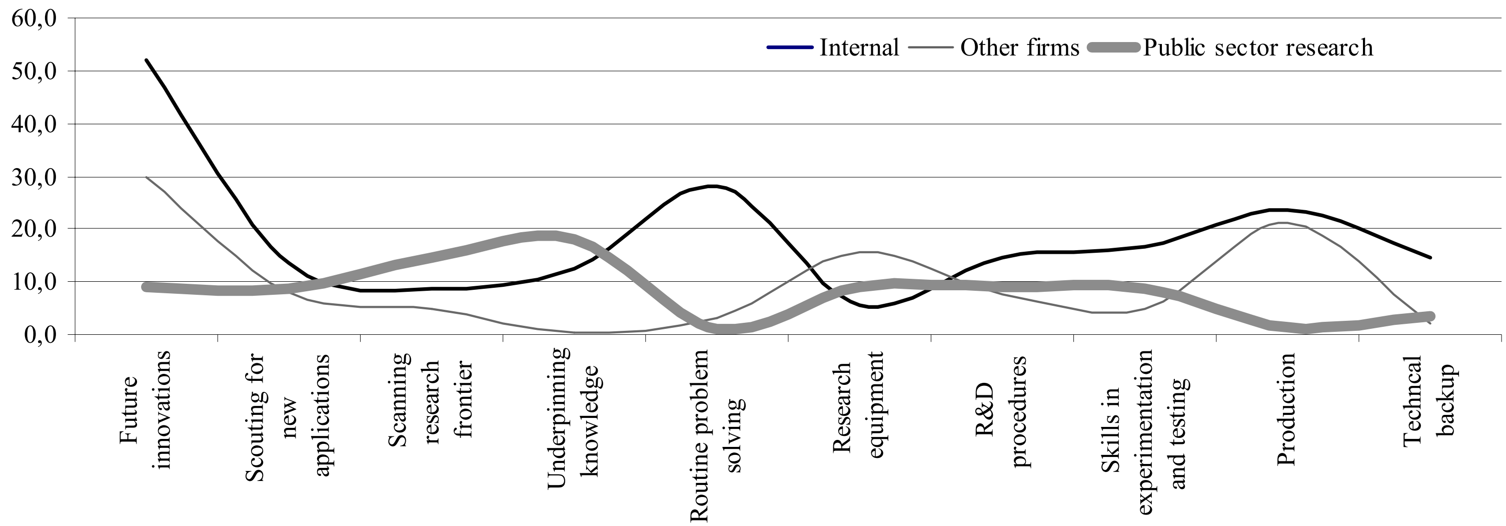
Source: Gibbons, Johnston 1974

Appendix 9. Relevance of sources of knowledge in the innovation process (units)



Source: Gibbons, Johnston 1974.

Appendix 10. Relevance of sources of knowledge in the innovation process (%)



Source: Faulkner et al. 1995: 222.

Appendix 11. Relevance of sources of knowledge by sectors (%)

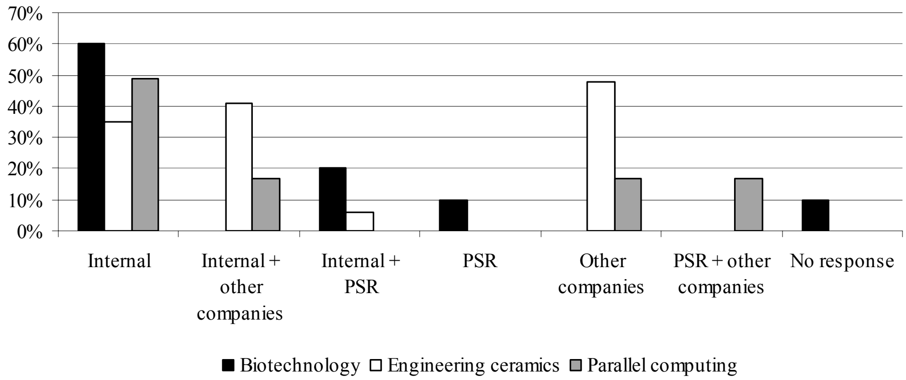


Figure 1. Sources of knowledge for identifying new product ideas (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

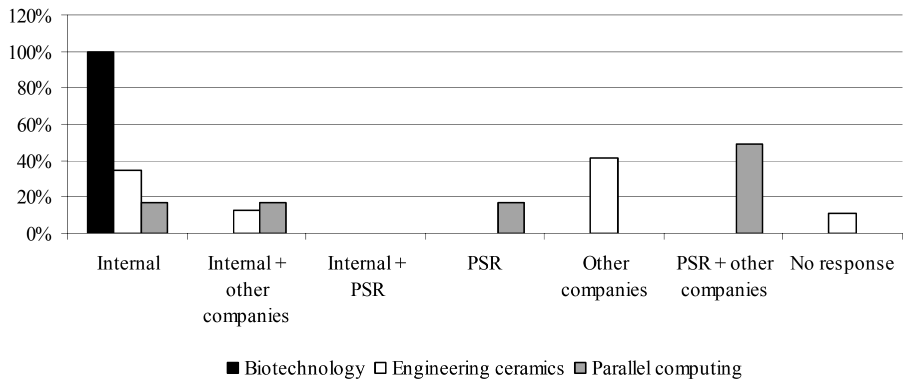


Figure 2. Sources of knowledge for articulating user needs (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

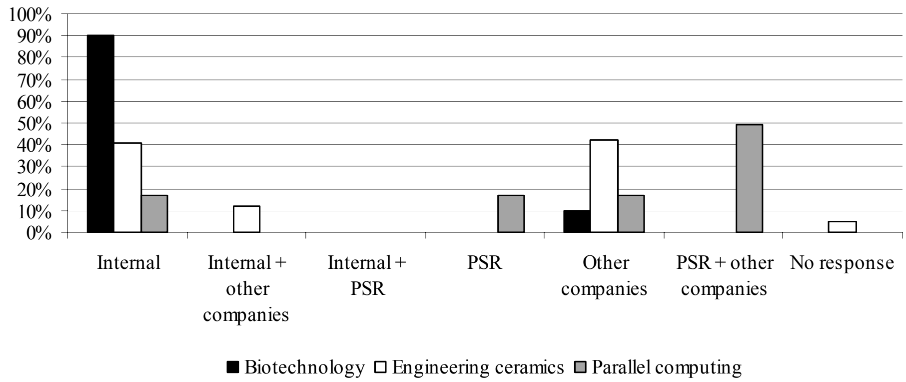


Figure 3. Sources of knowledge for receiving feedback for existing products (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

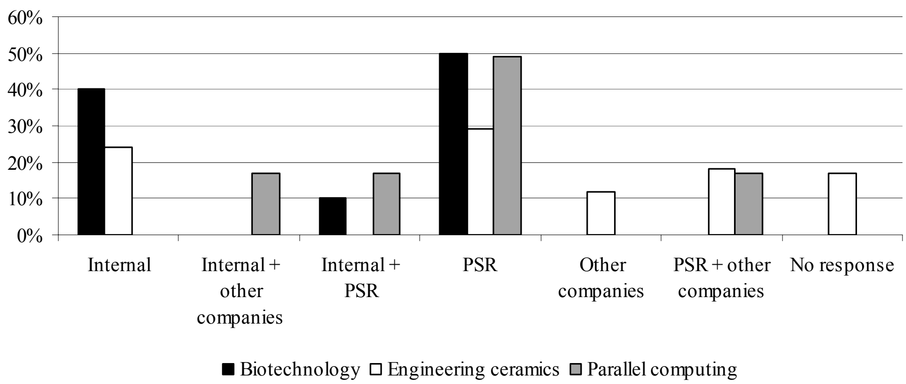


Figure 4. Sources of knowledge for scouting for new applications (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

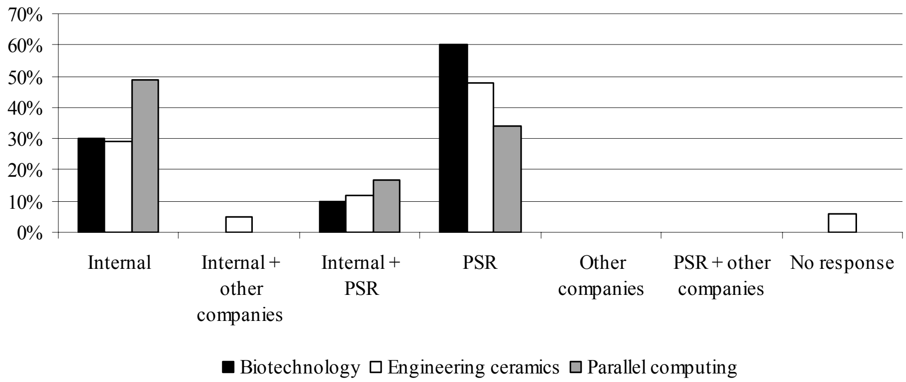


Figure 5. Sources of knowledge for underpinning knowlegde (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

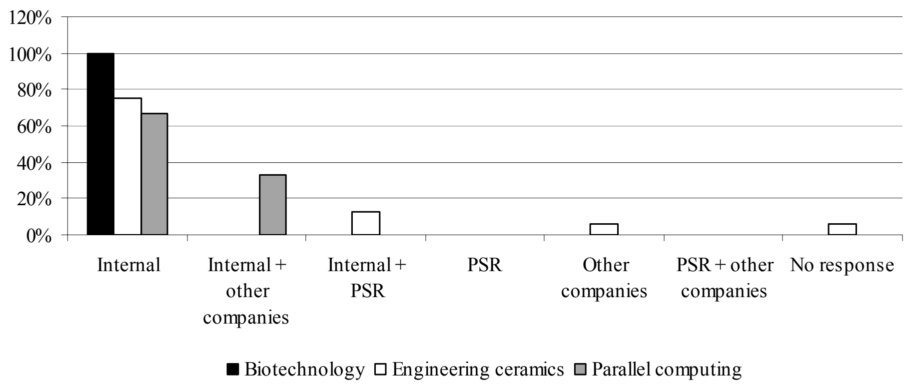


Figure 6. Sources of knowledge for routine problem-solving (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

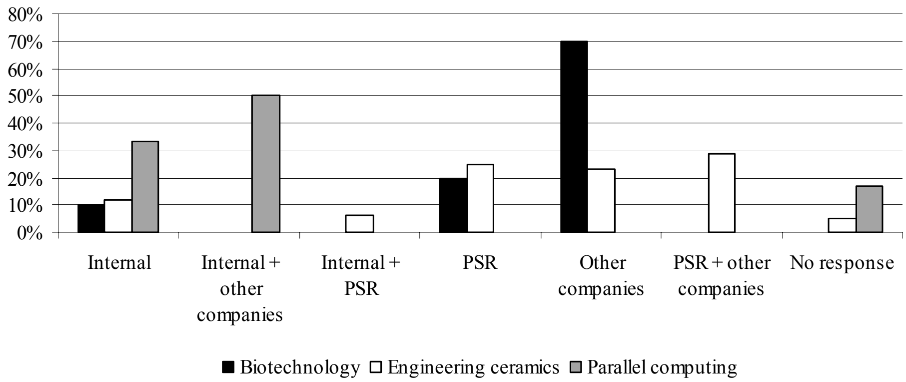


Figure 7. Sources of knowledge for new research equipment (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

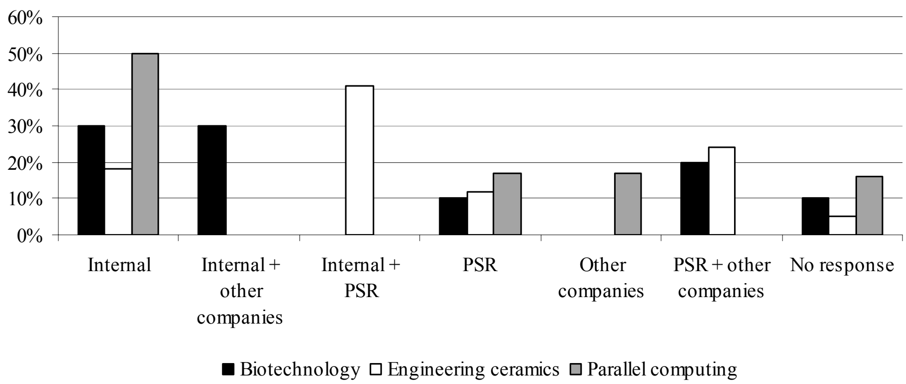


Figure 8. Sources of knowledge for new R&D procedures (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

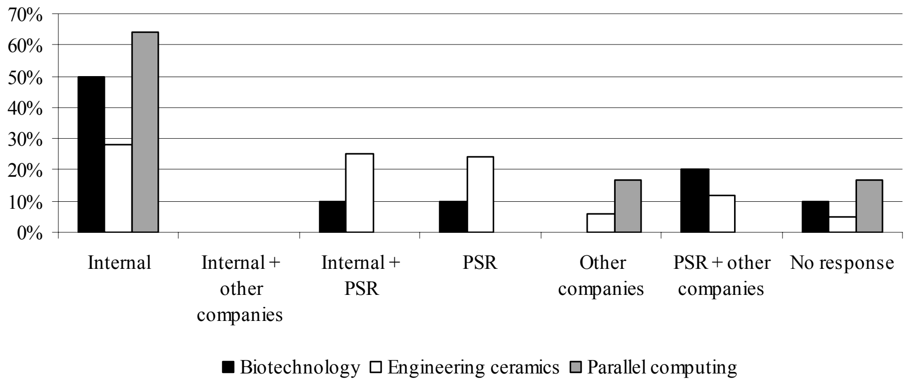


Figure 9. Sources of knowledge for skills in experimentation and testing (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

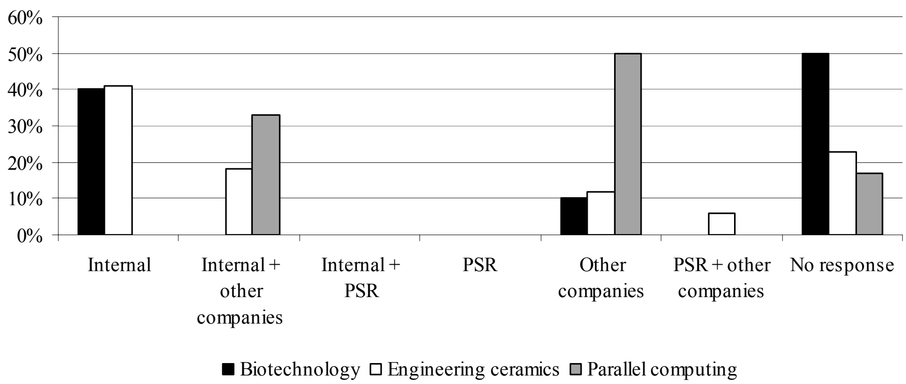


Figure 10. Sources of knowledge for new process technologies (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

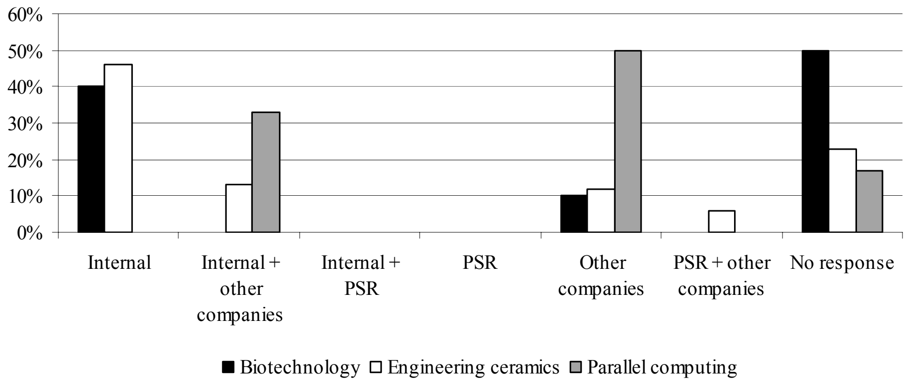


Figure 11. Sources of knowledge for new production methods (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

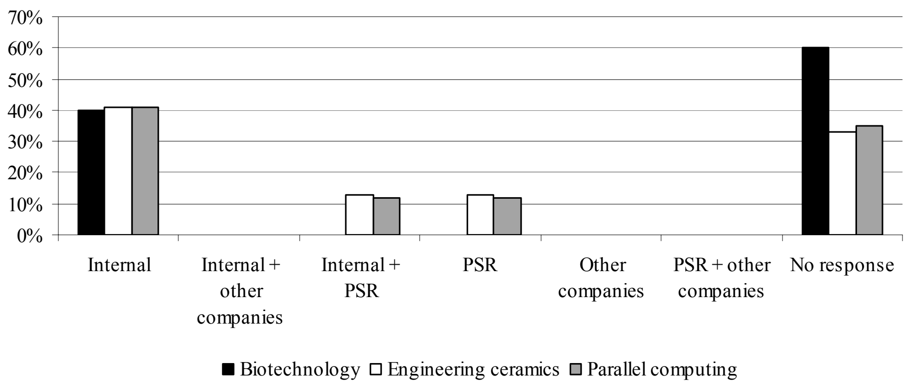


Figure 11. Sources of knowledge for technical back-up (Author's compilation of Faulkner et al. 1995: 91, 127, 166)

Table 1. Relevance of knowledge sources by sectors

Relevance of knowledge sources (% of responses)	Biotechnology	Engineering Ceramics	Parallel Computing
Internal > External	55	59	100
Internal = External	18	6	–
Internal < External	27	35	–
	100	100	100
PSR > Other firms	67	35	8
PSR = Other firms	33	24	38
PSR < Other firms	–	41	54
	100	100	100

Source: Faulkner et al. 1995: 71–72,112,146–147

Appendix 12. Relevance of public sector research (PSR) contacts by type (%)

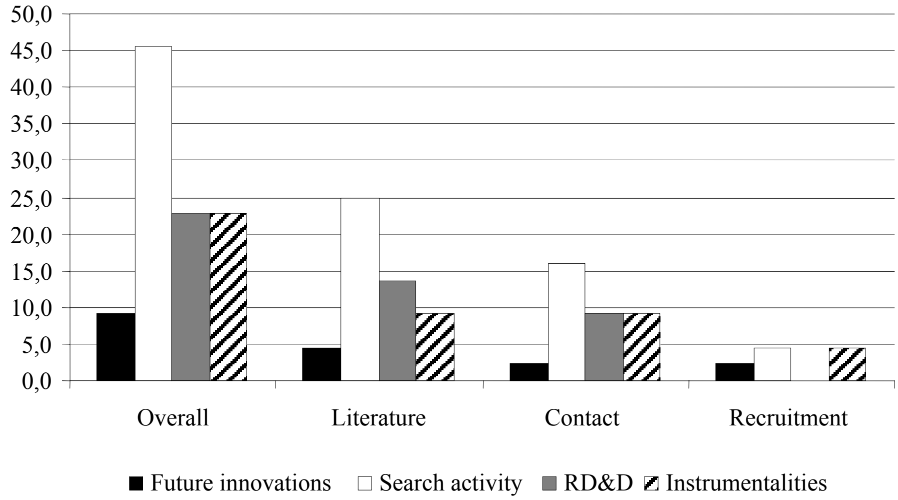


Figure 1. Relevance of different PSR contacts in biotechnology (Faulkner et al. 1995: 92, 128, 168)

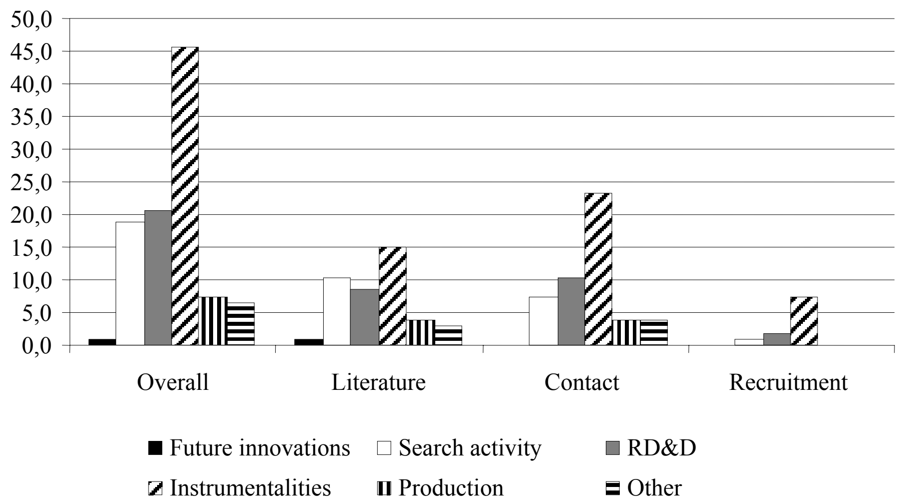


Figure 2. Relevance of different PSR contacts in engineering ceramics (Faulkner et al. 1995: 92, 128, 168)

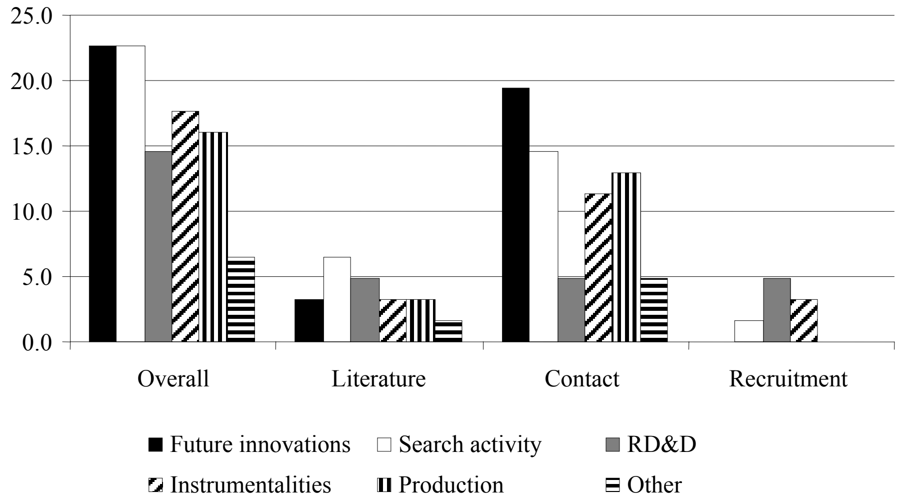


Figure 3. Relevance of different PSR contacts in parallel computing (Faulkner et al. 1995: 92, 128, 168)

Appendix 13. Questionnaire of ERIS innovation strategy study

BACKGROUND INFORMATION

Company, products, markets, competition

1. *How has the main profile of the company changed since the start-up? (including the position in the value-chain) (Strongly-moderately-not at all; what are the main changes?)*
2. *Number of workers*
3. *Type of ownership; changes if occurred.*
4. *Which changes in the nomenclature of products have occurred? (Including the scope of portfolio; homogeneity-heterogeneity).*
5. *Assessment of the (production) technology? (The source and age of technology? How it satisfies the company's needs; whether it can be considered as a critical factor at the moment?)*
6. *Frome where comes the main input for the company? (raw materials, components etc)*
7. *How much are the domestic suppliers used in comparison with foreign? Are they competitive compared to foreign ones? Would it be considered to use more domestic suppliers and on what conditions?*
8. *What are the main target markets and how the product is distributed?*
    a. Main target markets
    b. Distribution channels (trader, own sales representatives etc.)
    c. How does the domestic demand differ from the export demand? How the company does respond to those differences?
    d. Is the distribution going to be changed in the nearest future?
9. *What is the main characteristic of the competitive advantage in main markets? (price, design, quality, novelty, flexibility, delivering time, service etc)*
10. *Is the main competitive advantage going to be change significantly in the nearest future?*
11. *What is the main threat to the company in following 3 years period?*

MAIN STUDY

Innovation and its motives

1. *If the company has launched new or significantly improved products in past three years; what have been the main changes in products?*

2. *If the company has used new or significantly improved technologies in past three years; what have been the main changes in technologies?*
3. *What changes have occurred in the company more broadly (organisation etc)?*
4. *Has the speed of innovation processes satisfied the company?*
5. *What are the main plans in following three years:*
    a. *Regarding products*
    b. *Regarding technologies*
    c. *Regarding organisation (quality certificates, distribution channels, reorganisation of the company etc)*
6. *What is the main driver or motive for changes?*
7. *What are the main barriers for innovations?*
8. *How the R&D is financed?*
    a. *Are the bank credits used, are the support schemes of Enterprise Estonia (or other state support) used in addition of own finances of the company?*
    b. *Is it difficult to collect finances for innovation?*

Co-operation (including innovation co-operation)

9. *How important is the co-operation with other companies in the same sector?*
10. *In what fields is the co-operation most important or necessary?*
11. *Has the intensity of co-operation relationships been sufficient in all the fields relevant for your company?*
12. *How the co-operation could to be improved?*
13. *What have been the main problems in co-operation with partners?*
14. *Who (and where) are the main innovation partners? (e.g. 3most important ones)?*
15. *How does the co-operation process looks like?*
16. *How you assess the innovation co-operation of your company? Is it relevant for the company's development?*
17. *Have you already co-operated with educational institutions (vocational schools, universities etc.) or plan such kind of co-operation? Please, specify!*

Plans, barriers and public support needed for R&D activities

18. *What are the main goals of the company for following years considering the business plan? Please, select 3 most important ones and order them by relevance (1 – most relevant goal)*

a. increasing turnover
b. increasing market share
c. recruitment of complementary workers (please, specify, what type of workers)
d. adapting new technology
e. increasing profitability/effectiveness
f. replacement of products/services
g. development of new products
h. improvement in the flexibility of production
i. cutting production costs
j. implementing the system of quality control
k. improvement of working conditions
l. improvement of marketing strategy
m. other…………………………………………..

19. *What are the main barriers for developing the company? Please, select 5 most important ones and order them by relevance (1 – most relevant barrier)*

a. innovations are too costly / lack of finances
b. long payback period for investments
c. lack of experience and knowledge within enterprise
d. problems of communication and co-operation within enterprise
e. negative attitude towards changes within enterprise
f. lack of employees with suitable skills
g. innovations are easily imitated or copied
h. high costs, too long processes of enforcement for intellectual property protection
i. lack of possibilities for co-operation
j. lack of technological information
k. lack of technological potential
l. lack of technological support services
m. lack of consumer responsiveness
n. increase of input prices (incl. wages)
o. lack of infrastructure
p. tax policy or other regulations
q. other…………………………………..……………..

20. *What are the aspects in the local environment that are supporting/ hindering the development of the company? (Why are you located here?)*

21. *What services of public support infrastructure are you using (e.g. development centres by county governments, technology parks, Enterprise Estonia)? What services are you missing?*

22. *What kind of help, if any, would you expect from the local and/or central government for implementing your development plans?*

Appendix 14. List of interviewed firms and managers

No	Name of the Company and Manager, Date of the Interview
1	*AS Cista,* Mr. Vahur Käärik, 01.09.2006
2	*AS Ecobirch,* Mr. Gert Rahnel, CEO, 15.09.2006
3	*AS Estonia Klaverivabrik*, Mr. Indrek Laul, CEO, 27.06.2006
4	*AS Flexa Eesti*, Mr. Kurt Jespersgaard, Member of the Board, 26.05.2006
5	*AS Lemeks,* Mr. Jüri Külvik, CEO, 03.07.2006
6	*AS Rait*, Dr. Ivar Dembovski, CEO, 17.08.2006
7	*AS Rakvere Metsamajand*, Mr. Andres Alamets, CEO, 26.05.2006
8	*AS Repo Vabrikud*, Mr. Tiit Kolk, CEO; Ms. Lilian Niitsoo, Marketing Manager, 12.09.2006
9	*AS Räpina Paberivabrik*, Mr. Meelis Mälberg, CEO, 22.05.2006
10	*AS Wermo,* Mr. Tarmu Ossip, 22.05.2006
11	*AS Vinnal,* Mr. Ville Timmi, 10.08.2006
12	*Haapsalu Uksetehase AS,* Mr. Ago Soomre, 06.06.2006
13	*HM Puidukaubanduse OÜ,* Mr. Andrus Ilumets, 15.08.2006
14	*OÜ Matek,* Mr. Sven Mats, CEO, 15.06.2006
15	*OÜ TNC Components,* Mr. Kaido Toome, CEO, 02.06.2006
16	*OÜ Vesset,* Mr. Kalle Kruus, Owner, and Mr. Toomas Pertel, CEO, 15.08.2006
17	*RMK*, Mr. Ülo Viilup, CEO, 08.06.2006
18	*Skan Holz Helme AS*, Mr. Argo Mehide, CEO, 02.07.2006
19	*UPM-Kymment Otepää AS*, Mr. Ando Jukk, CEO, 06.07.2006

Appendix 15. Results of the interviews

Table 1. Components of the Objective Functions of Managers

No	Profit today	Future profits (sustainability)	Labour	Other	Respondent
1	+	+			Manager
2	+	+ (efficiency)	+ (wages)	Technological investments, quality of products	Owner & manager
3				Being ahead of competitors, decreasing labour costs through technological investments	Manager
4		+ (survival, efficiency)	+ (in terms of easier work for empoloyees)		Manager
5		+ (efficiency, sustainability, innovativeness as a mean)			Owner & manager
6	+	+	+ (wages)		Manager
7		+ (sustainability)			Owner & manager
8				Demand trends, Competition	Owner & Manager
9	+	+		Growth of firm (turnover), Customer satisfaction	Owner & Manager
10				Quality of product	Owner and Manager
11	3	2	1 (attracting H-Q labour)	In order to be sustainable, you need hq labour first	Owner and Manager
12	+	+	+	Competition Image of the firm	Manager
13	+	+ (efficiency)		Improvement of quality	Manager
14	3	1	2 (welfare of labour)		Owner & manager(s)
15	+	+	+		Manager
16		+ (specifics of forestry)	+		Owner & manager
17			+		Owner & manager
18		+ (in terms of proportionality btw wages and productivity)	+ (motivation)		Owner & manager
19	+				Manager

Note: + means the presence of the component in objective function; numbers mean the rank in the objective function

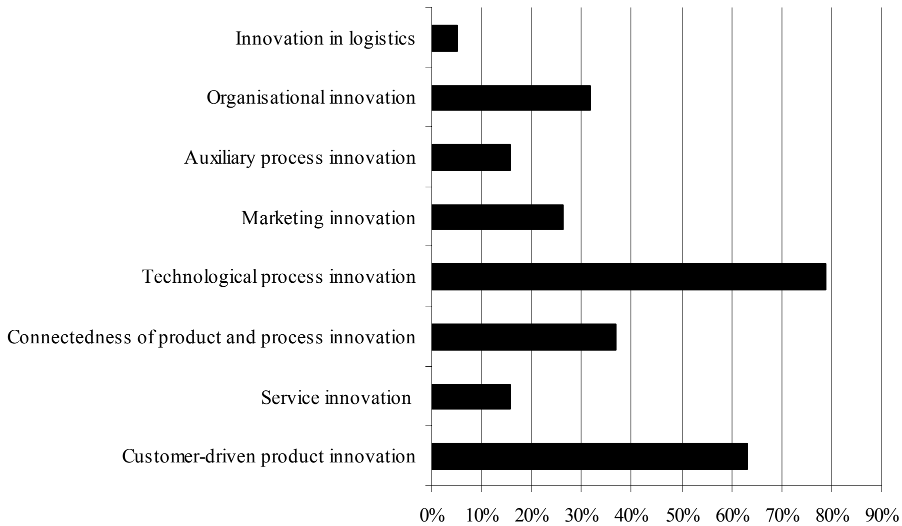


Figure 1. Share of respondent firms conducting different types of innovations

Table 2. The main goals of the company for following years considering the business plan

Goal	**14**	**16**	**15**	**18**	**17**	**19**	**1**	**2**	**3**	**13**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Average score**
Goals given in the questionnaire																				
Increasing turnover			2	3		2	4				3					5		1.5		1.08
Increasing market share																				0.00
Recruitment of complementary workers																				0.00
Adapting new technology		2						3	1			2	1	3		4			4	1.05
Increasing profitability/effectiveness				2		3	5	5	3	5			3					1.5		1.45
Replacement of products/services																				0.00
Development of new products		3					3		5			2	2	4						1.00
Improvement in the flexibility of production		1	1		3						1				3		3			0.63
Cutting production costs				1		1		1	2		2			1	2		2			0.63
Implementing the system of quality control								2				2								0.21
Improvement of working conditions			3		1												1			0.26
Improvement of marketing strategy					2				4					2						0.42
Other goals, added by respondent																				
Sustainability	3													5	5				5	0.95
Employees (development, satisfaction)	2							4												0.32
New markets																		3		0.16

Note: In the questionnaire, 3 most important goals was asked to mark and order them by relevance (3 – most relevant goal, 2 – second and 1 – least relevant), in case the order of goals was not possible to establish, the average ranks were used.

Table 3. The main barriers for developing the company

Barrier	14	16	15	18	17	19	1	2	3	13	4	5	6	7	8	9	10	11	12	Average score
Goals given in the questionnaire																				
Innovations are too costly / lack of finances				3		5				4				3						0.79
Long payback period for investments				1	1						5	3	1							0.58
Lack of experience and knowledge within enterprise		3			2	4	4	4			2	3		4	4					1.58
Problems of communication and co-operation within enterprise				4								3			1					0.42
Negative attitude towards changes within enterprise															5			2.5	5	0.66
Lack of employees with suitable skills			4	2	3	3	5	5	5	5	3	3	3	5	3	5		2.5		2.97
Innovations are easily imitated or copied																				0.00
Too long processes of enforcement for intellectual property protection																				0.00
Lack of possibilities for co-operation																				0.00
Lack of technological information																				0.00
Lack of technological potential											1									0.05
Lack of technological support services		3										3	4					2.5		0.66
Lack of consumer responsiveness																				0.00
Increase of input prices (incl. wages)		3			1	2	3				4						2	5		1.05
Lack of infrastructure		3	2	1		1		3					2							0.63
Tax policy or other regulations		3			4								5				1			0.68
Other goals, brought out by respondent																				
Lack of will, way of thinking of entrepreneur himself	5																			0.26
Lack of cooperation btw municipal governments			5																	0.26
Wage competition as a disadvantage to forest sector			4																	0.21
(Brutal) flexibility of exchange rates																	5			0.26
Estonia – lacking image as a producer of brands																	4			0.21
Uncertainty of following topics (EUR currency, energy prices, wages)															2		3			0.26
Lack of raw material with suitable quality									4											0.21

Note: The respondents were asked to select 5 most important ones and order them by relevance (5 – most relevant barrier)

Appendix 16. A set of initial research hypotheses

Table 1. Innovative Activities and Sources of Knowledge: Research Hypotheses

Innovative Activity	Operational Variable	Source of Knowledge	No.
Market finding	Innovation in internal knowledge management, Relational innovations	Internal sources are used for knowledge management and relational innovations Consultants are used for knowledge management and relational innovations	1 2
Synthetic design Detailed design and testing	Design innovation Product innovation Service innovation	Internal sources are used for product innovations Customers are used for product innovations Suppliers are used for product innovations Industrial associations and competitors are used for product innovations Universities and R&D institutes are used product and service innovations	3 4 5 6 7
Redesigning and producing	Process innovation Auxiliary process innovation	Internal sources are used for all types of process innovations Suppliers are used for all types of process management innovations Customers are used for all types of process innovations Consultants are used for all types of process innovation	8 9 10 11
Distribution and marketing	Marketing innovations Logistics innovations	Internal sources are used for logistics innovations Customers are used for marketing innovations Suppliers are used for logistics innovations	12 13 14

Table 2. Choice of the Sources of Knowledge and Underlying Influencing Factors: Research Hypotheses for Multiple Sources

Source of Knowledge	Factor Groups Influencing the Choice	Hypotheses	No.
Internal, all external	Attributes / technology or industry related factors	Firm size is positively associated with using internal as well as external knowledge sources.	15
		Firms with more intensive R&D and personnel development activities are relaying more on all knowledge sources.	16
	Internal and external environment	Organisational and personnel constraints are discouraging factor for using the knowledge sources.	17
External business sources	Attributes / technology or industry related factors	Exporters are using more external business sources	18
	Internal and external environment	External business sources are used more in firms with risk barriers to innovation.	19
		Financial barriers are discouraging the use of external knowledge sources (except for competitors).	20
	Innovation cooperation	Existence of formal cooperation agreements is encouraging factor of knowledge exchange (except for competitors).	21
External public research sources	Attributes / technology or industry related factors	Firms with higher spending on R&D are using more intensively universities as knowledge sources.	22
	Internal and external environment	Firms with higher expenditures on training have more knowledge exchange with universities and R&D institutes	23
		Universities and R&D institutions are used for gathering technological as well as market knowledge	24

Table 3. Choice of the Sources of Knowledge and Underlying Influencing Factors: Research Hypotheses for Single Sources

Source of Knowledge	Factor Groups Influencing the Choice	Hypotheses	No
Internal sources	Firm attributes / technology or industry related factors	Firms with more intensive R&D and personnel development activities can relay more on internal sources while innovating.	25
	Factors of innovation cooperation	Internal sources are used for cooperative innovation projects.	26
Suppliers	Firm attributes / technology or industry related factors	Suppliers are used more in firms with substantial investments into process technologies	27
	Factors of internal and external environment	Suppliers are used for diminishing the barrier of lacking technological knowledge.	28
	Factors of innovation cooperation	The lack of suppliers with suitable capabilities can be a hindering factor for supplier cooperation.	29
Customers	Firm attributes / technology or industry related factors	Customers are used for novel product innovations Customers are used by exporting firms	30
	Factors of internal and external environment	Customers are used to reduce the barrier of lacking market knowledge	31
	Factors of innovation cooperation	Non-responsive customers are causing firms to cooperate more with customers to eliminate this barrier. Non responsive customers are discouraging the knowledge exchange with customers.	32
Competitors and industry associations	Firm attributes / technology or industry related factors	Concern members are using less knowledge exchange with competitors Exporters are using more competitors and industry associations	33
	Factors of internal and external environment	Firms with legal barriers use more competitors and industry associations	34
	Factors of innovation cooperation	Formal cooperation arrangements are not relevant to competitors cooperation Formal cooperation arrangements are relevant for cooperation with industry associations	35
Consultants	Factors of internal and external environment	Firms with financial barriers use less consultants	36
Universities	Factors of internal and external environment	Universities are used for knowledge exchange in relation to novel products	37
	Factors of innovation cooperation	Formal cooperation is not encouraging factor	38
Literature	Factors of internal and external environment	Literature is used by firms having high financing barriers Literature is used to gather technological knowledge	39

Table 4. Complementarity and Substitutability of the Internal Sources of Knowledge With External Knowledge Sources: Research Hypotheses

Source of Knowledge	Description	No
Internal and external	External knowledge sources are complements to firm's internal knowledge sources and hence the increase in the interaction intensity with them would intensify the use of internal knowledge sources.	40
Internal and external	External knowledge sources are substitutes to firm's internal knowledge sources and hence the increase in the interaction intensity with them would decrease the use of internal knowledge sources.	41

Table 5. Complementarity and Substitutability of the Internal Sources of Knowledge With External Knowledge Sources: Research Hypotheses

Sources of Knowledge	Description	No
Universities, public sector R&D institutes and all other external sources	Universities and public R&D institutes are complements to all other external knowledge sources and hence the increase in the interaction intensity with them would intensify the use of external knowledge sources.	42
Customers, suppliers and other external sources	Customers and suppliers as knowledge sources are complements to other internal knowledge sources and hence the increase in the interaction intensity with them would increase the use of other external knowledge sources.	43
Universities and public R&D institutes	Universities and public R&D institutes are considered to be substitutes offering similar knowledge.	44

Appendix 17. Descriptive statistics of CIS 4 sample

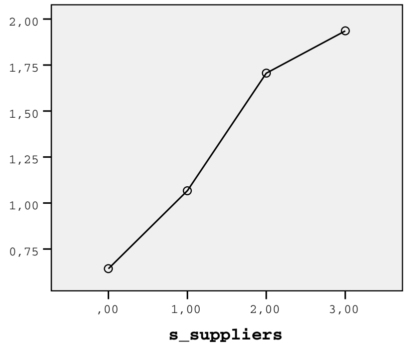
	N	Range	Min.	Max.	Mean		Std. Dev.	Variance
Variable name	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
B_finance	120	3.00	.00	3.00	1.6667	.10803	1.18345	1.401
B_innov costs	120	3.00	.00	3.00	1.3750	.10456	1.14541	1.312
B_law	120	3.00	.00	3.00	.6583	.08156	.89345	.798
B_market know	120	3.00	.00	3.00	1.0167	.09317	1.02066	1.042
B_no demand	120	3.00	.00	3.00	.9750	.08814	.96548	.932
B_org	120	3.00	.00	3.00	.5417	.07660	.83913	.704
B_personnell	120	3.00	.00	3.00	1.2833	.09844	1.07831	1.163
B_risk	120	3.00	.00	3.00	.8833	.08711	.95428	.911
B_tech know	120	3.00	.00	3.00	.9917	.08410	.92123	.849
C_competitors	120	3.00	.00	3.00	.2000	.05626	.61631	.380
C_concern	120	3.00	.00	3.00	.3083	.08182	.89627	.803
C_consultants	120	3.00	.00	3.00	.1083	.04065	.44525	.198
C_customers	120	3.00	.00	3.00	.4583	.09311	1.01993	1.040
C_RDinstitutes	120	2.00	.00	2.00	.0417	.02481	.27181	.074
C_suppliers	120	3.00	.00	3.00	.5083	.09687	1.06112	1.126
C_universities	120	3.00	.00	3.00	.0583	.03197	.35017	.123
Concern	120	1.00	.00	1.00	.3417	.04348	.47626	.227
Empl	120	.00	.00	.00	.0000	.00000	.00000	.000
Exports	120	1.00	.00	1.00	.5131	.03446	.37754	.143
Foreign	120	1.00	.00	1.00	.3250	.04294	.47034	.221
Innov costs	120	133.93	.00	133.93	1.2826	1.12144	12.28471	150.914
Procinno	120	1.00	.00	1.00	.6500	.04372	.47897	.229
Prodinno	120	1.00	.00	1.00	.6750	.04294	.47034	.221
S_competitors	120	3.00	.00	3.00	1.2417	.08615	.94376	.891
S_concern	120	3.00	.00	3.00	.5917	.10076	1.10382	1.218
S_conferences	120	3.00	.00	3.00	.8667	.09008	.98675	.974
S_consultants	120	3.00	.00	3.00	.3250	.06280	.68798	.473
S_customers	120	3.00	.00	3.00	1.5583	.09958	1.09080	1.190
S_fairs	120	3.00	.00	3.00	1.3500	.09217	1.00962	1.019
S_internal	120	3.00	.00	3.00	1.8417	.09467	1.03709	1.076
S_R&D institutes	120	3.00	.00	3.00	.1167	.03958	.43354	.188
S_suppliers	120	3.00	.00	3.00	1.6083	.09922	1.08694	1.181
S_universities	120	2.00	.00	2.00	.1333	.03730	.40859	.167
S_universities	120	1.00	.00	1.00	.1083	.02849	.31210	.097
Sales	120	627077	34	627111	38533	7686	84196	7089115220

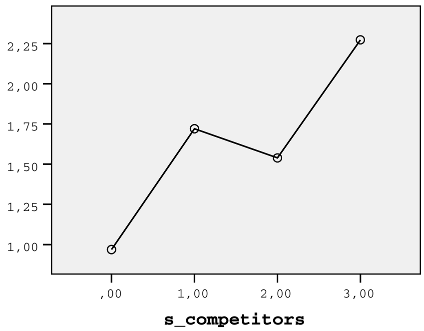
Appendix 18. Descriptive statistics of CIS 4 sample

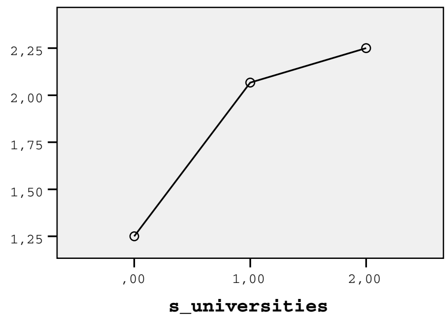
	N	Range	Min	Maxi	Mean		Std. Dev.	Variance
Variable Name	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
B_dominant firms	139	3.00	.00	3.00	1.0144	.09017	1.06312	1.130
B_earlier innov	139	3.00	.00	3.00	.6043	.08144	.96021	.922
B_external finance	139	3.00	.00	3.00	1.1295	.10405	1.22672	1.505
B_innov costs	139	3.00	.00	3.00	1.4173	.10103	1.19115	1.419
B_internal finance	139	3.00	.00	3.00	1.7266	.09623	1.13448	1.287
B_market know	139	3.00	.00	3.00	.9065	.07968	.93941	.882
B_no demand	139	3.00	.00	3.00	.6619	.07679	.90533	.820
B_no partners	139	3.00	.00	3.00	.8201	.08185	.96498	.931
B_personnell	139	3.00	.00	3.00	1.5252	.09209	1.08568	1.179
B_risk	139	3.00	.00	3.00	.9065	.08718	1.02782	1.056
B_techn know	139	3.00	.00	3.00	.9712	.08036	.94748	.898
C_competitors	139	1.00	.00	1.00	.0647	.02095	.24697	.061
C_concern	139	1.00	.00	1.00	.0288	.01423	.16778	.028
C_consultants	139	1.00	.00	1.00	.0504	.01862	.21948	.048
C_customers	139	1.00	.00	1.00	.0791	.02298	.27093	.073
Concern membership	139	1.00	.00	1.00	.4101	.04187	.49363	.244
Concern prodinno	139	1.00	.00	1.00	.0360	.01585	.18689	.035
Continuous RD	139	1.00	.00	1.00	.2086	.03459	.40780	.166
Cooper prodinno	139	1.00	.00	1.00	.1511	.03049	.35942	.129
C_RDinst	139	1.00	.00	1.00	.0072	.00719	.08482	.007
C_supplierr	139	1.00	.00	1.00	.1295	.02858	.33696	.114
C_universities	139	1.00	.00	1.00	.0360	.01585	.18689	.035
Designinno	139	1.00	.00	1.00	.2446	.03659	.43141	.186
Domestic market	139	1.00	.00	1.00	.7914	.03459	.40780	.166
Empl	139	827.00	10.00	837.00	97.5683	11.04117	130.17347	16945.131
EU market	139	1.00	.00	1.00	.9281	.02200	.25933	.067
Export	139	1.00	.00	1.00	.4900	.03084	.36354	.132
Own prodinno	139	1.00	.00	1.00	.3813	.04135	.48746	.238
Foreign	139	1.00	.00	1.00	.3237	.03983	.46959	.221
Auxc inno	139	1.00	.00	1.00	.3094	.03935	.46390	.215
Local market	139	1.00	.00	1.00	.6475	.04067	.47948	.230
Logistics innov	139	1.00	.00	1.00	.1151	.02717	.32031	.103
Machinery costs	139	2.08	.00	2.08	.0560	.01756	.20707	.043
Knowledge manag innov	139	1.00	.00	1.00	.3165	.03959	.46681	.218
Marketing innov	139	1.00	.00	1.00	.2158	.03502	.41288	.170
National gov support	139	1.00	.00	1.00	.0935	.02479	.29222	.085
Occasional RD	139	1.00	.00	1.00	.1079	.02641	.31139	.097
Procinno	139	1.00	.00	1.00	.4892	.04255	.50169	.252
Concern procinno	139	1.00	.00	1.00	.0360	.01585	.18689	.035

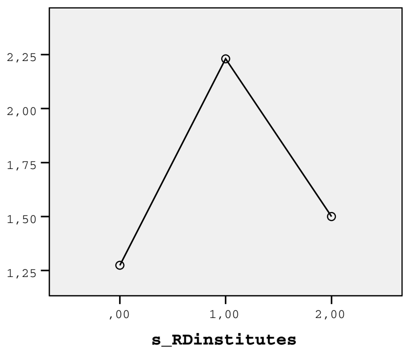
Variable Name	N	Range	Min	Maxi	Mean		Std. Dev.	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Cooperative procinno	139	1.00	.00	1.00	.1295	.02858	.33696	.114
Own procinno	139	1.00	.00	1.00	.3381	.04027	.47478	.225
Prodinno	139	1.00	.00	1.00	.5683	.04216	.49710	.247
Relational innov	139	1.00	.00	1.00	.3094	.03935	.46390	.215
S_associations	139	2.00	.00	2.00	.2950	.05049	.59531	.354
S_competitors	139	3.00	.00	3.00	.9784	.08752	1.03187	1.065
S_conferences	139	3.00	.00	3.00	1.2518	.09308	1.09739	1.204
S_consultants	139	3.00	.00	3.00	.3669	.06629	.78152	.611
S_customers	139	3.00	.00	3.00	1.2950	.09976	1.17617	1.383
S_internalconcern	139	3.00	.00	3.00	1.3669	.10716	1.26344	1.596
S_journals	139	3.00	.00	3.00	.6403	.07075	.83412	.696
S_RDinstitutes	139	2.00	.00	2.00	.1223	.03141	.37028	.137
S_suppliers	139	3.00	.00	3.00	1.5108	.09707	1.14441	1.310
S_universities	139	2.00	.00	2.00	.1655	.03765	.44391	.197
Sales	139	6.71	7.20	13.91	10.2845	.11781	1.38894	1.929
Sales new to firm	139	1.00	.00	1.00	.1639	.02288	.26975	.073
Sales new to market	139	.80	.00	.80	.0361	.00955	.11264	.013
Service innov	139	1.00	.00	1.00	.1007	.02562	.30205	.091
Total innov costs	139	2.08	.00	2.08	.0595	.01772	.20886	.044
Workorg innov	139	1.00	.00	1.00	.4892	.04255	.50169	.252

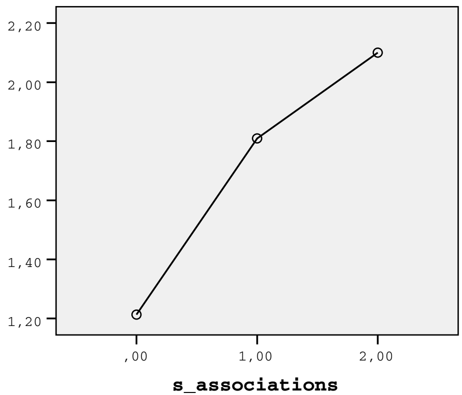
Appendix 19. Estimated marginal means for the internal and concern knowledge sources

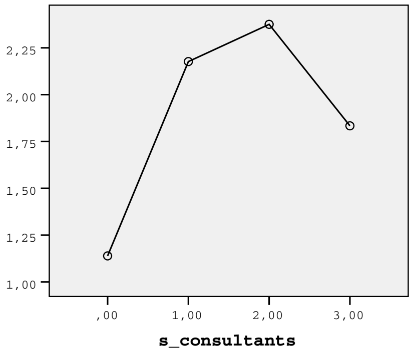








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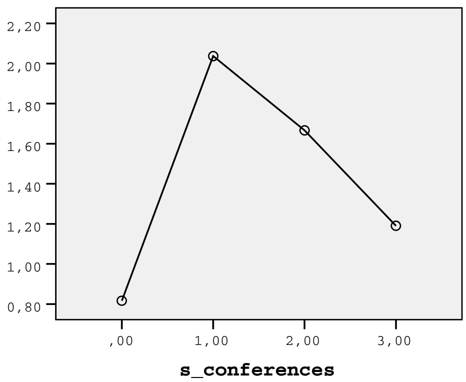
1,00
2,00
3,00
s_consultants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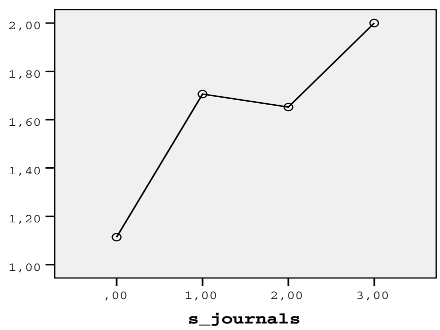
,00
1,00
2,00
3,00
s_conferences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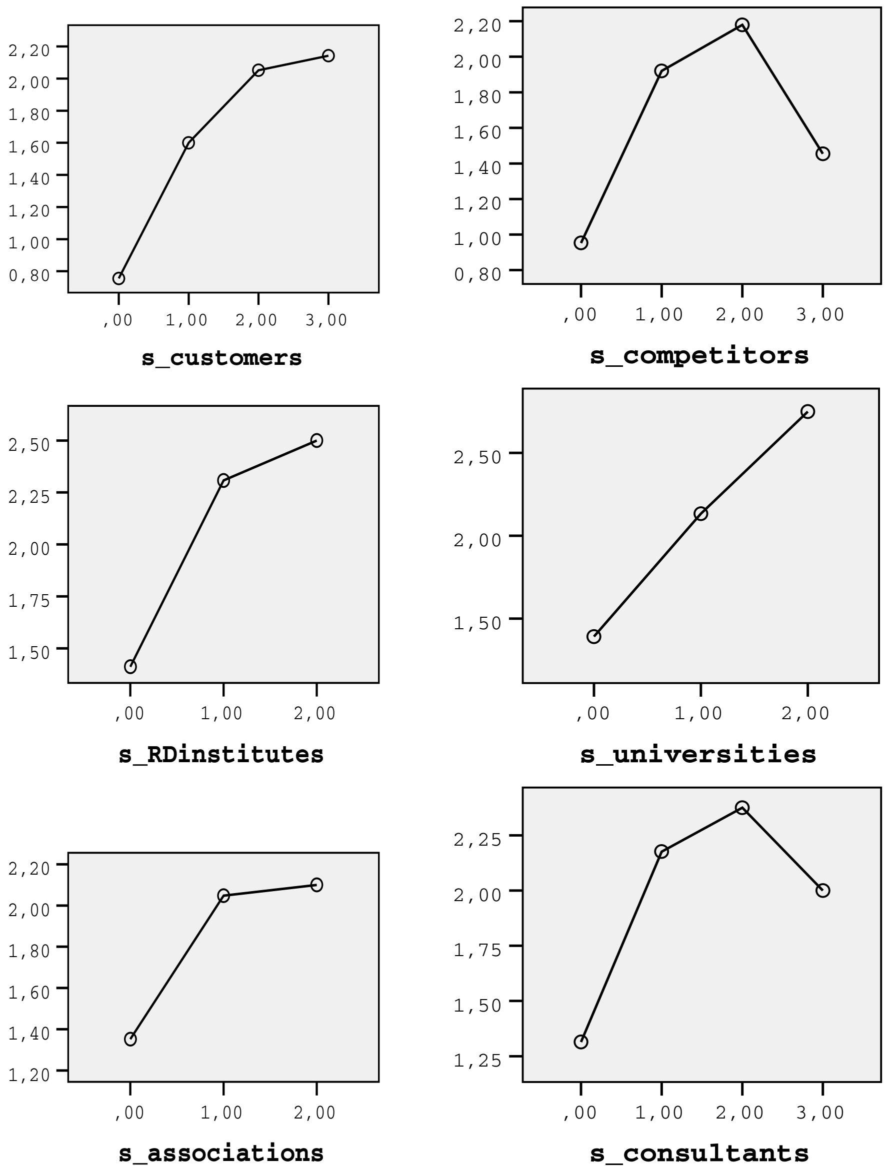
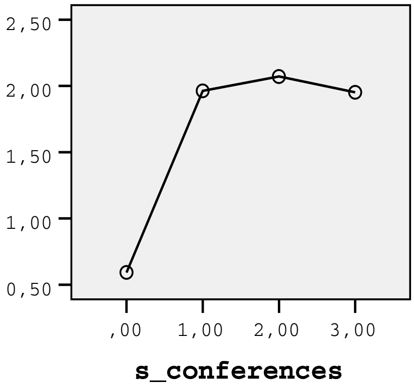
2,00
3,00
s_journals

Appendix 20. Estimated marginal means for the suppliers as knowledge sources

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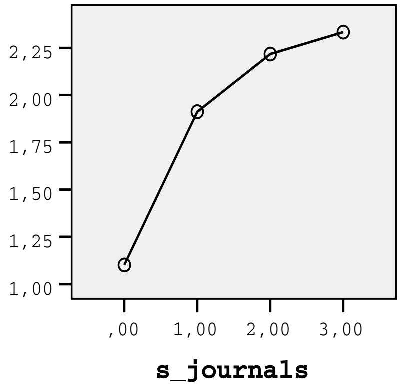
s_conferences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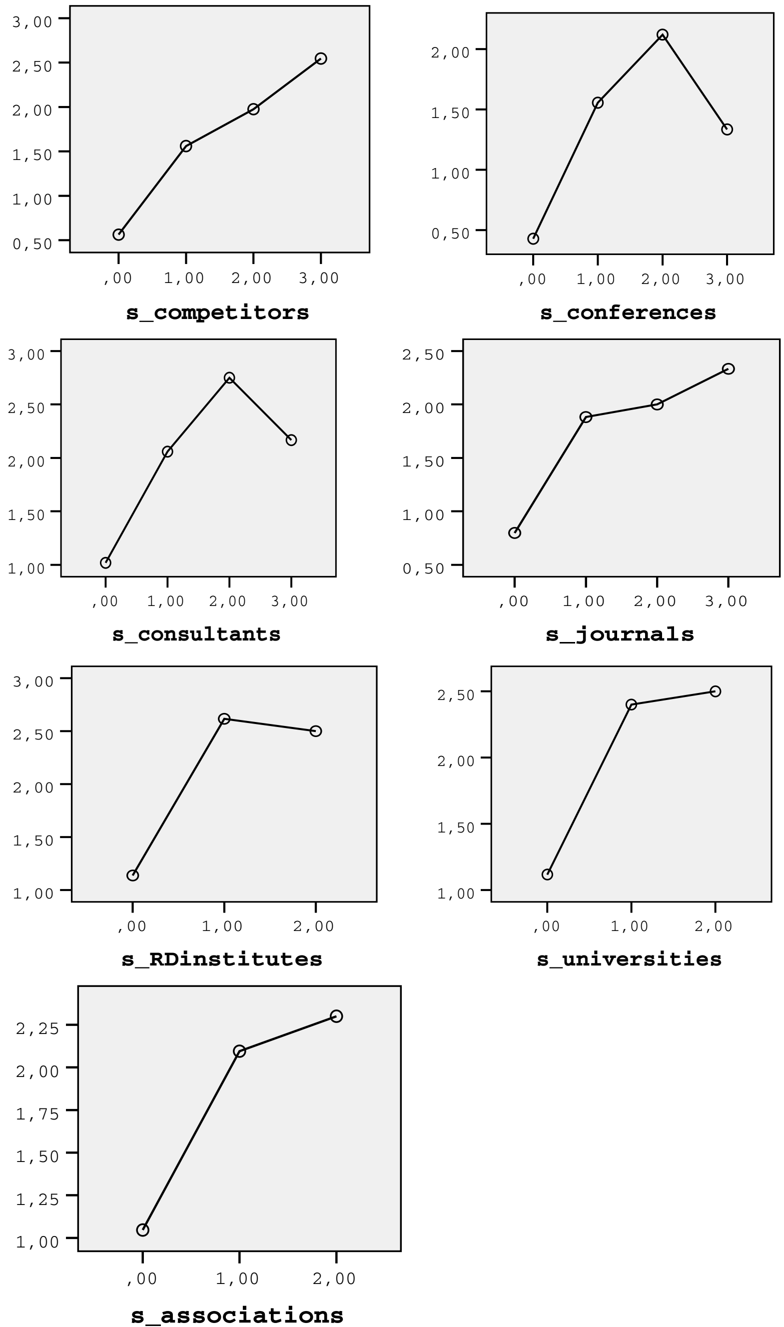
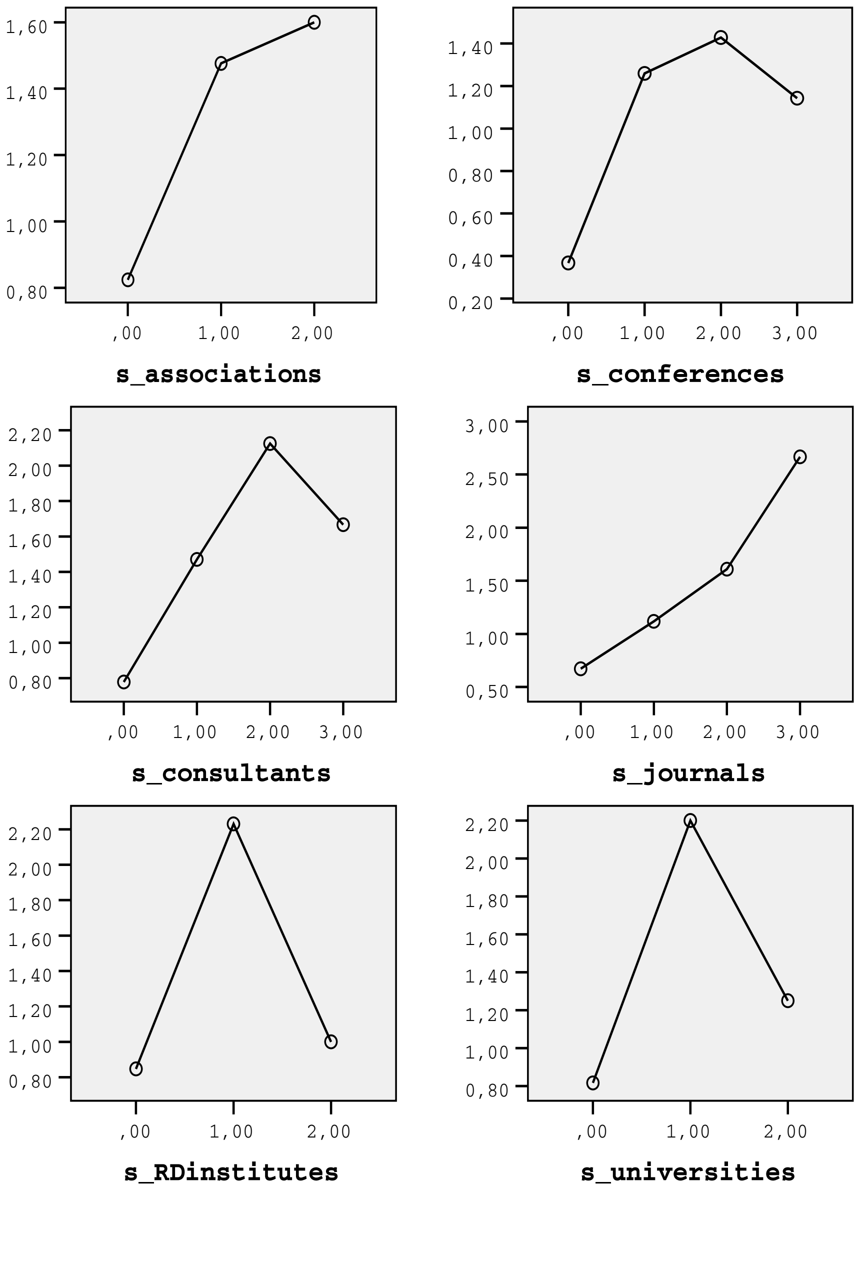
1,50
1,25
1,00
,00
1,00
2,00
3,00
s_journals

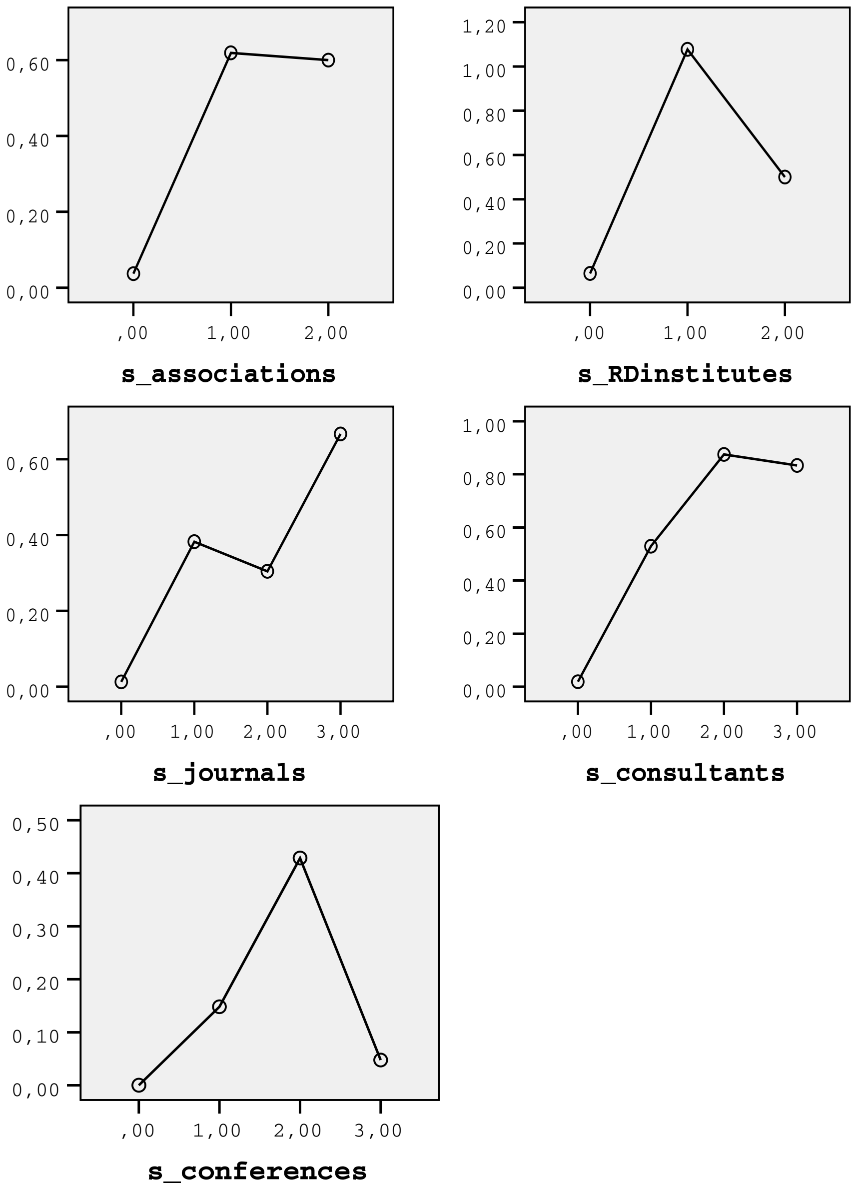
Appendix 21. Estimated marginal means for the customers as knowledge sources



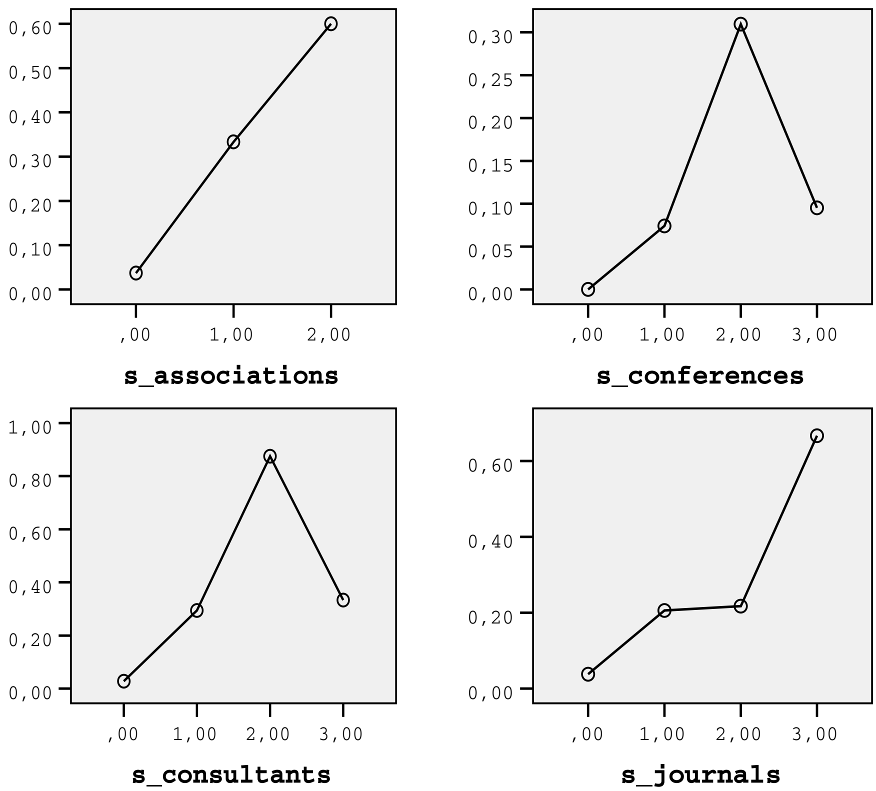
Appendix 22. Estimated marginal means for the competitors as knowledge sources



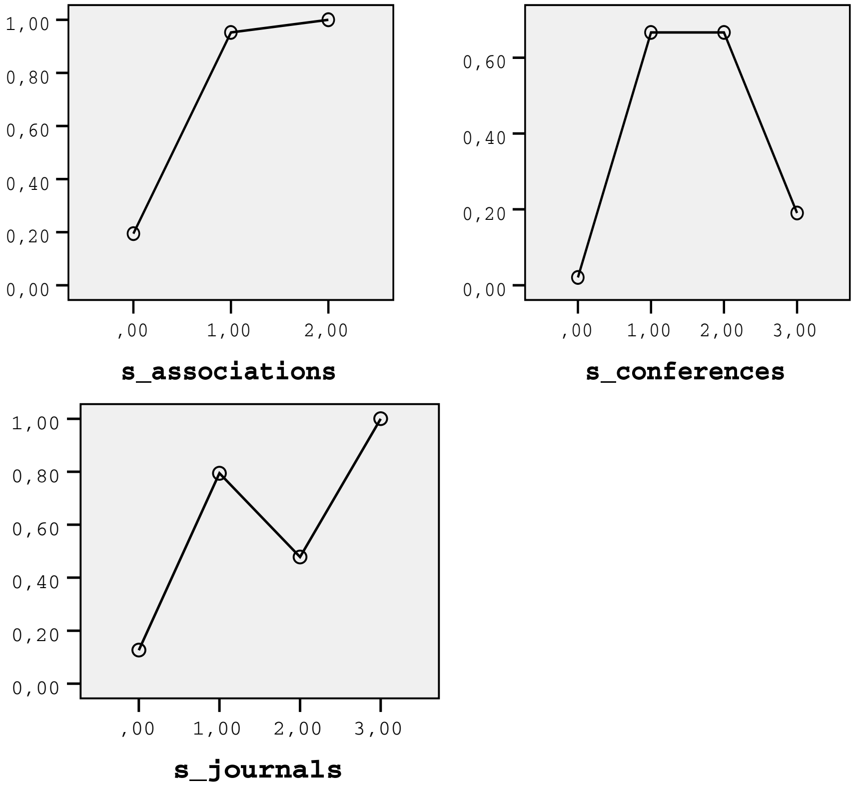
Appendix 23. Estimated marginal means for the universities as knowledge sources



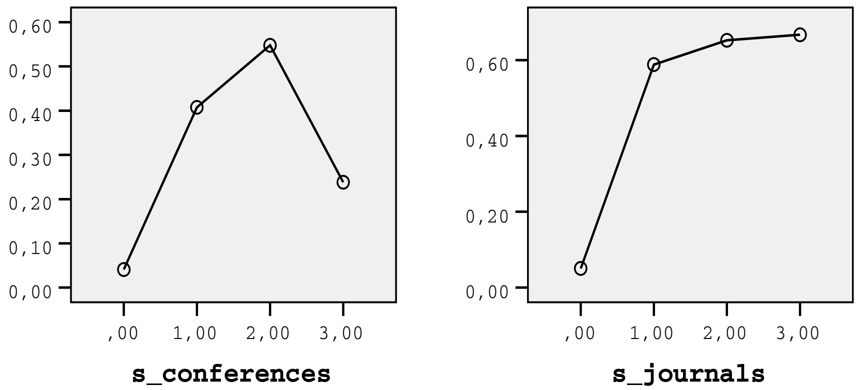
Appendix 24. Estimated marginal means for the R&D institutes as knowledge sources



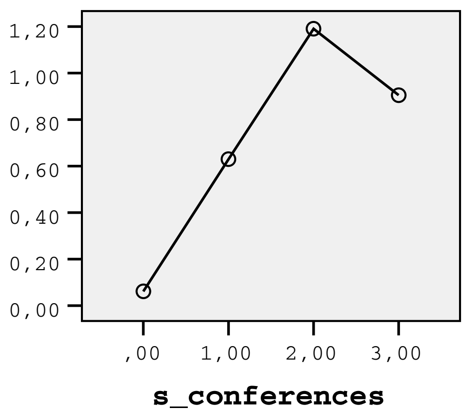
Appendix 25. Estimated marginal means for the consultants as knowledge sources



Appendix 26. Estimated marginal means for the industry associations as knowledge sources



Appendix 27. Estimated marginal means for the journals as knowledge sources



Appendix 28. Results of policy simulation for the aggregated probabilities to innovate

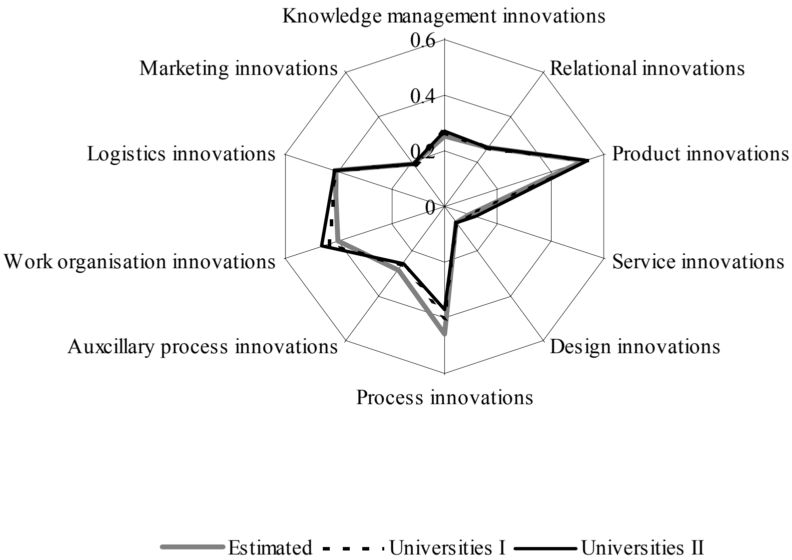


Figure 1. Average probabilities to innovate with policy directed at strenghthening the universities.

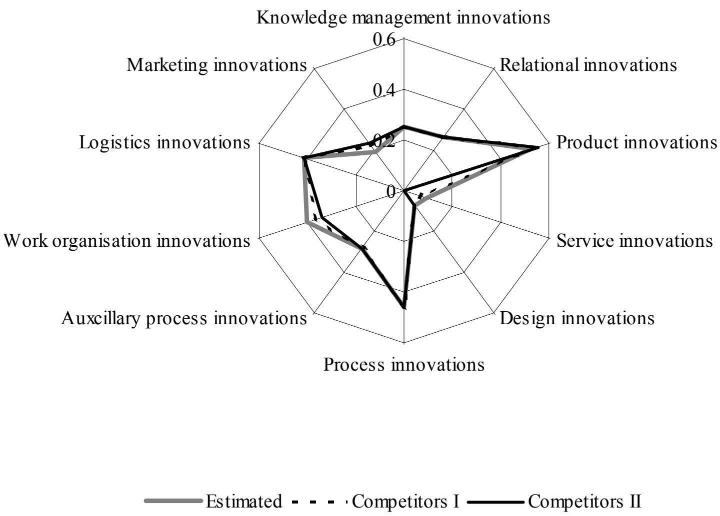


Figure 2. Average probabilities to innovate with policy directed at strenghthening the competitor collaboration.

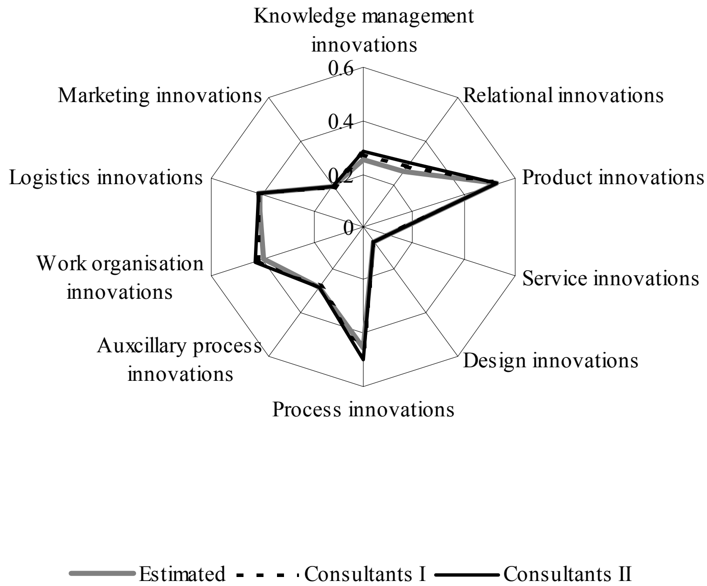


Figure 3. Average probabilities to innovate with policy directed at supporting the use of consultants for innovation processes.

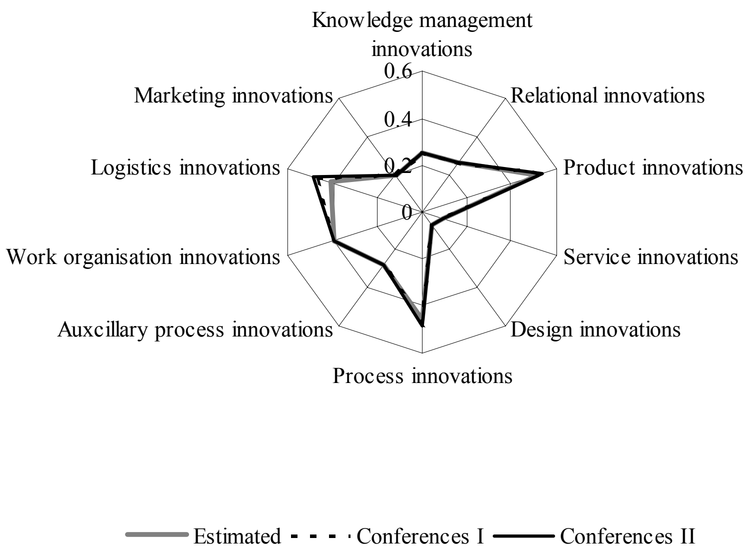


Figure 4. Average probabilities to innovate with policy directed at supporting the use of conferences for innovation processes.

Appendix 29. Results of policy simulation for the individual probabilities to innovate

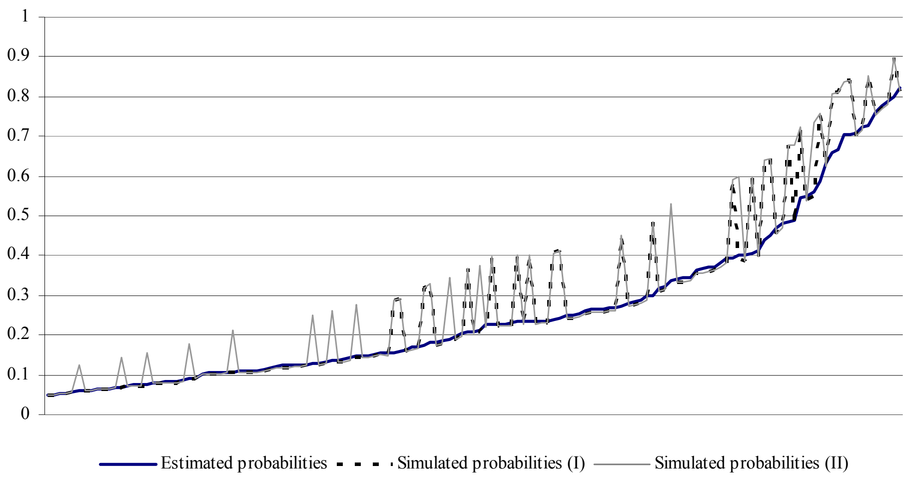


Figure 1. Individual probabilities to conduct knowledge management innovations

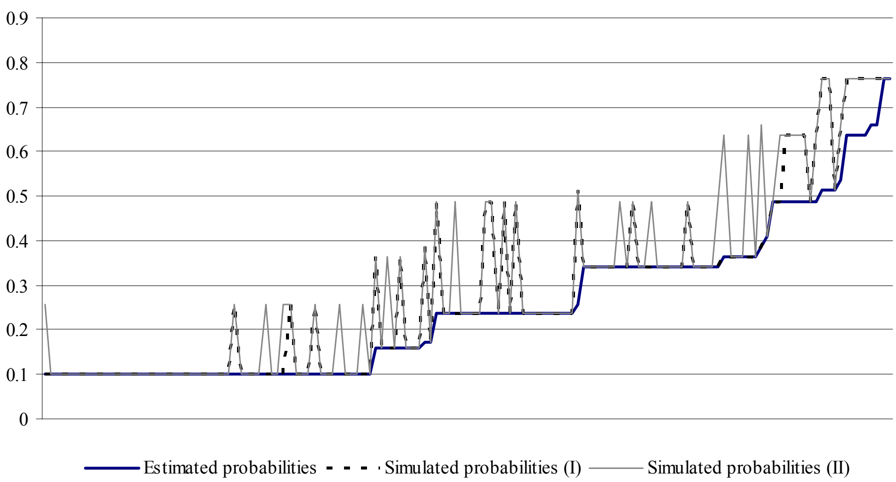


Figure 2. Individual probabilities to conduct relational innovations

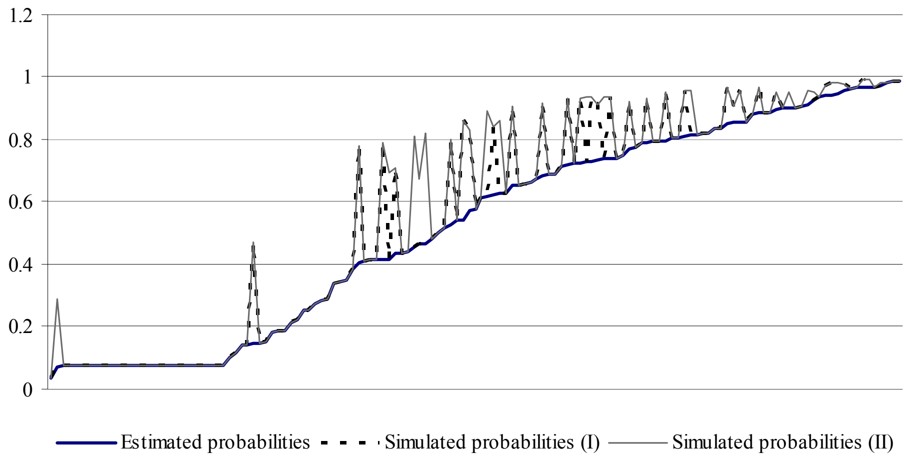


Figure 3. Individual probabilities to conduct product innovations

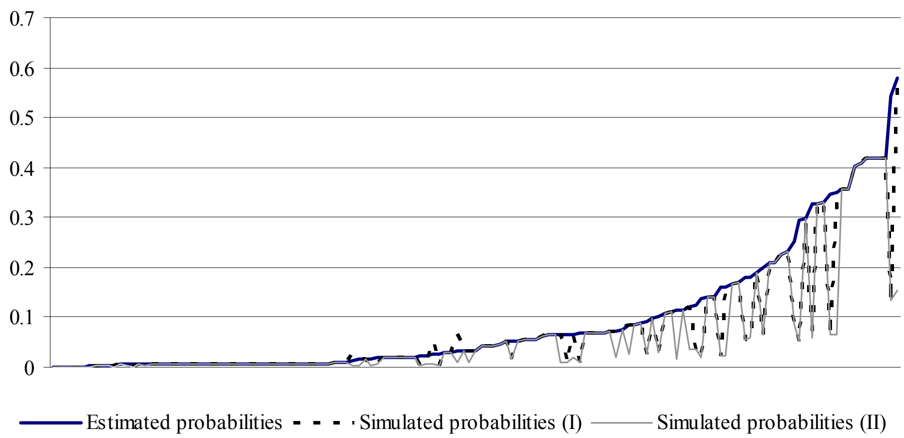


Figure 4. Individual probabilities to conduct service innovations

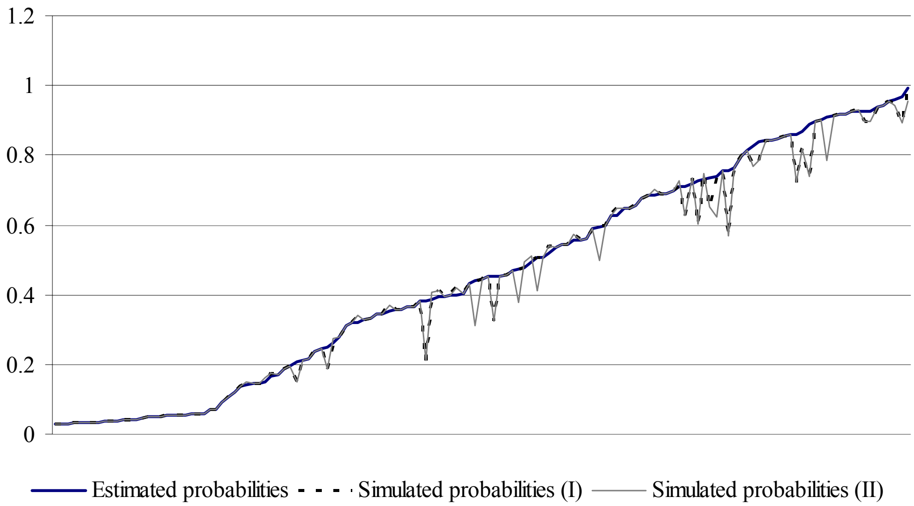


Figure 5. Individual probabilities to conduct technological process innovations

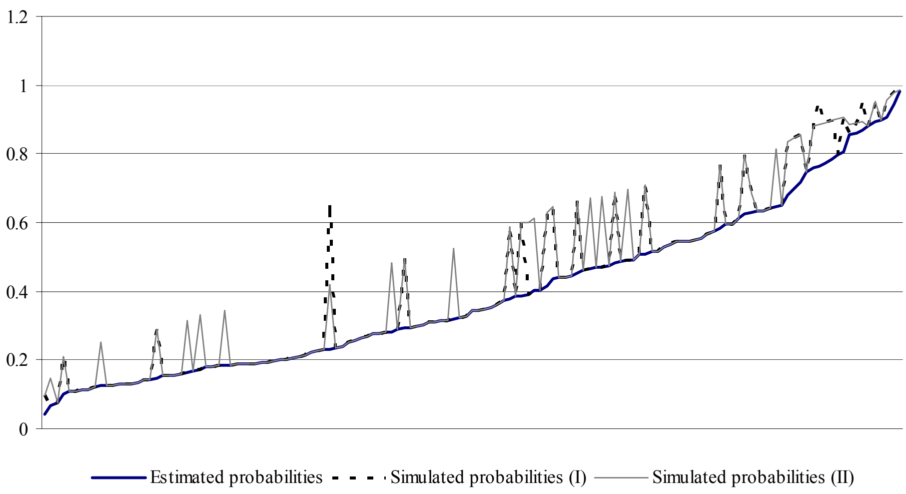


Figure 6. Individual probabilities to conduct innovations in work organisation.

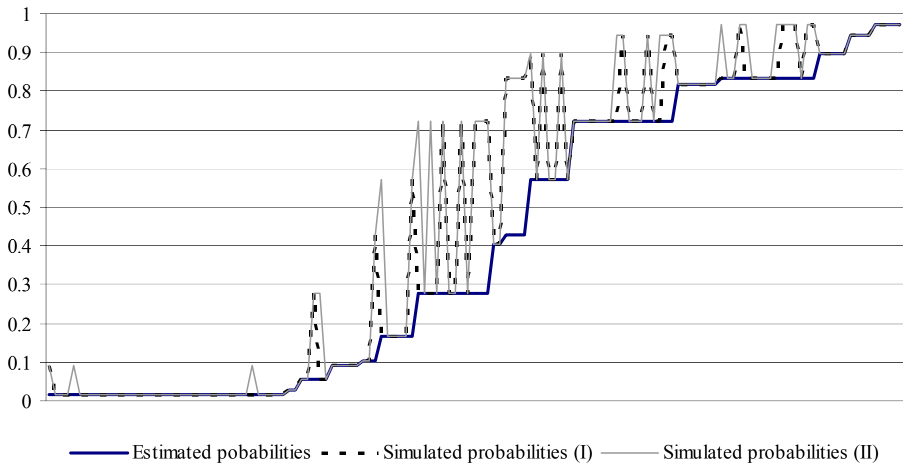


Figure 7. Individual probabilities to conduct process innovations in logistics.

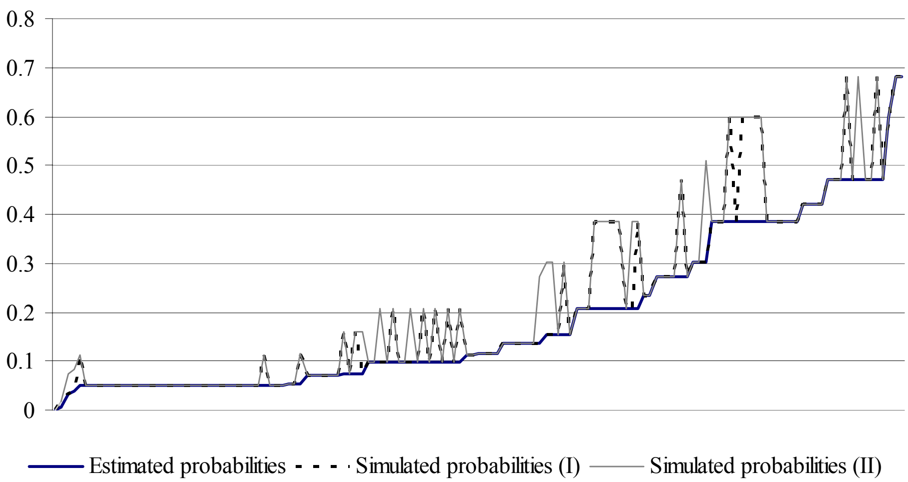


Figure 8. Individual probabilities to conduct marketing innovations.

SUMMARY IN ESTONIAN – KOKKUVÕTE

Innovatsioniteadmuse allikad Eesti puidusektori näitel

Töö aktuaalsus

Innovaatilisus on üks olulisemaid ettevõtete konkurentsivõimet pikas perspektiivis tagavaid tegureid. Mitmed evolutsioonilise majandusteooria suuna esindajad (Nelson, 1995; Dosi, 1997; Metcalfe, 1998), samuti teadmuspõhise majanduse ideid kandvad autorid (Lundvall, 1995; Lundvall ja Johnson, 1994; Cowan et al. 2000) on pidanud teadmust (*knowledge*) keskseks teguriks ühiskonna innovatsioniportsesside kujundamisel. Vastavaid õppimisele tuginevaid protsesse on nimetatud nii teadmuspõhiseks ühiskonnaks (*knowledge economy*) (Drucker, 1993) kui ka innovatsioonipõhiseks tootmiseks *(innovation-mediated production*) (Florida, Kenney, 1993). Selle kirjanduse kohaselt sõltub majanduse, samuti üksikute ettevõtete tulemuslikkus olemasoleva teadmuse jagamise, levitamise (*knowledge dissemination*) ja kasutamise efektiivsusest ning uue teadmuse loomise kiirusest ja levitamisest. Peamine väide seisneb selles, et väärtusloome ja kasumi peamine allikas on nihkunud füüsiliselt tööjõult ja manuaalsetelt oskustelt intellektuaalsetele oskustele ja teadmistele, seejuures on nii uurimis- ja arendustöö tegijad kui ka tehasetöölised uute ideede ja pideva innovatsiooni kandjateks (Florida, 2002). Majandusteadues käsitletakse mitmetes traditsioonilistes firmateooriates ettevõtet kui reaktsiooni teadmusega seotud probleemidele (mikroökonoomika erinevad laiendused – transaktsioonikulude teooria, informatsiooniteooria), samas on uuemad lähenemisviisid (evolutsiooniline majandusteooria, ressursipõhine firmateooria jne.) rõhutanud ettevõtte kui teadmuse kogumi olulisust. Seejuures nähakse innovatsiooni kui teadmuse loomise protsessi tulemust või väljundit. Innovatsiooniks on vaja nii vastavate sisemiste ressursside olemasolu ettevõttes kui ka võimet saada ideid väljastpoolt ja neid siis oma ettevõttes rakendada.

Arusaam teadmuse rollist innovatsiooniprotsessides on aja jooksul muutunud ja täiustunud. Esialgu vaadeldi teadmuse rolli innovatsiooniprotsessis lineaarsena (kas siis teadusest tuleneva tõukeimpulsi või turult tuleva tõmbetegurina). Sellise mudeli kriitika toodi välja peamiselt juhtumiuuringute abil, millega näidati lineaarse mudeli liigset lihtsustatust nii tehnoloogia arengu kui ka teaduse arengu selgitamisel (Faulkner, 1994). Innovatsioon ei ole ainult ettevõttesisene tegevus, see nõuab ettevõtetelt aktiivset uute teadmiste ja tehnoloogia allikate otsimist ning nende rakendamist oma toodetes ja/või tootmisprotsessides (Roelandt, den Hertog, 1999). Sellise käsitlusviisi alguseks peetakse Lundvalli (1995) artiklit ning see on mõneti erinev varasematest innovatsioonikäsitlustest, mis rõhutasid teaduse rolli ja/või turunõudluse rolli innovatsiooni esilekutsujatena. Innovatsioon nõuab kas uue teadmuse loomist või olemasoleva teadmuse teatud uuel viisil kombineerimist ning seega põhineb innovatsioon õppimisel, mis on suuresti sotsiaalne protsess – seda eriti kogemustele tugineva teadmuse (*tacit knowledge*) ülekandmise ja akumuleerimise puhul (Polanyi, 1966; Howells, 1995). Lundvalli (1995) kohaselt on innovatsiooniks olulised nii interaktiivne õppimine kui ka kollektiivne ettevõtlikkus – seega tuleb innovatsiooni vaadelda kui iteratiivset, kumulatiivset ning koostööl põhinevat nähtust (Freel, 2003). Kõigi eeltoodud teooriate kriitikaks võib pidada asjaolu, et teadmuse käsitlemine on jäänud üldiseks ning tööstusettevõtete innovatiooniprotsessides kasutatava teadmuse ja selle teadmuse allikate spetsiifikat on vähe uuritud.

Võrgustikuteooria väidab, et ettevõtted on harva võimelised eraldatuna innovatsioone läbi viima ning ei tee seda mitte kunagi nö suhete või informatsiooni vaakumis (Håkansson, 1987; Maillat, 1995; Florida, 1995; Baptista, Swann, 1998; Cooke, Morgan, 1998; Oughton, Whittam, 1997). Ettevõtete- või organisatsioonidevahelise koostöö kasulikkus seisneb eelkõige ressursside baasi ja kompetentsi laiendamises. Seega võib järeldada, et ettevõtte innovatsioonivõime paraneb laiema teadmiste baasi, kulude ja riski jagamisel, mis toimub läbi koostöö teiste subjektidega (näiteks tarnijate, klientide, konkurentide, ülikoolide jt koostööpartneritega) (vt ka Rothwell, 1991; Freel, 2000). Seetõttu on hakatud rääkima innovatsiooni süsteemsest olemusest, mis hõlmab lisaks teadmusele ka osalejad ja võrgustikud ning samuti institutsioonid, mis eeltooduid mõjutavad. Viimatimainitud kirjandusvaldkonna puuduseks on keskendatus suhteaspektidele võrgustikus osalejate vahel, see teadusvaldkond on sidumata konkreetse innovatsiooniteadmusega, mida nende võrgustike kaudu edasi kantakse.

Empiirilised uuringud on näidanud, et majandusharuti on innovatiivne tegevus väga erinev ja seetõttu on hakatud kasutama sektoraalse innovatsioonisüsteemi mõistet. Ei ole loodud küll vastavat teooriat, kuid on koostatud rida empiirilisi taksonoomiaid, mis kirjeldavad erinevaid mustreid, kuhu tööstusharud paigutuvad oma innovatsiooniprotsesside põhjal (üks tuntumaid on nt. Pavitt, 1984). Peamised sarnasused tulenevad erinevates harudes kasutatavatest sarnastest tehnoloogilistest režiimidest, teadmuse baasist ja õppimisprotsessidest (Breschi et al. 2000). Erinevused tulenevad majandusliku kasu saamise võimalustest (*appropriability conditions*) ja teadmuse akumuleerumisest, viimane tuleneb erinevate riikide teadussüsteemide eripäradest ning ettevõtete vaheliste võrgustike erinevustest (Nelson, 1993).

Tavaliselt keskenduvad innovatsiooni ja tehnoloogilisi muutusi uurivad teadustööd eelkõige teadusmahukatele tööstusharudele, mis on kõige modernsemad ja globaliseerunumad, teisi sektoreid on uuritud vähe. Siiski moodustavad ülalmainitud teadusmahukad sektorid suhteliselt väikese osa ka arenenud riikide majandustest, samal ajal kui näiteks puidul baseeruvad tööstusharud moodustavad väga olulise osa Soome, Rootsi, Austria ja ka Eesti majandusest. Lisaks eeltoodule on kommertsaspektist lähtudes edukaks osutunud innovatsioonid olnud pigem järk-järgulised kui radikaalsed uuendused tehnoloogia mõttes (Audretsch, 1995; Love, Roper, 1999).

Käesolev töö ühendab seega endas väga mitmeid teadmuse, innovatsiooni ja juhtimisalase teaduskirjanduse valdkondi – epistemoloogia, tehnoloogia ajalugu, tehnoloogia juhtimine, innovatsiooni ja informatsiooni teooriad, ressursipõhine firmateooria ja oganisatsiooni õppimise teooriad.

Uurimuse eesmärk ja ülesanded

Käesoleva doktoriöö eesmärgiks on innovatsiooniteadmuse olemuse, allikate ja mõjutegurite süvaanalüüsi kaudu määratleda erinevate teadmusallikate olulisus Eesti puidutööstusettevõtete innovatsiooniprotsessis. Puidusektori all mõistetakse käesolevas töös järgmisi puidul baseeruvaid tööstusharusid – puidutööstus, paberi- ja tselluloositööstus ning mööblitööstus. Kuigi eesmärk on suunatud kitsamalt puidusektori analüüsile, saab selle tulemusi kasutada laiemalt tööstusharus kasutatava teadmuse piiritlemiseks, samuti institutsionaalsete sektorite (tööstus- ja teadussektor) vahelise teadmuse piiritlemiseks ning lisaks ka teadmusvahetuse põhjuste ja piirangute hindamiseks.

Eesmärgi saavutamiseks on püstitatud järgmised uurimisülesanded:
1. määratleda innovatsiooniprotsessides kasutatava teadmuse sisu ja omadused;
2. määratleda allikad, mis erinevat tüüpi innovatsiooniteadmust kannavad;
3. tuua välja tegurid, mis mõjutavad ettevõtete innovatsiooniallikate valikut;
4. välja tuua puidusektori innovatsiooniteadmuse spetsiifika;
5. koostada ja hinnata empiirilised mudelid modelleerimaks ettevõtete valikuid teadmusallikate kasutamisel erinevate innovatsioonide lõikes;
6. koostada ja hinnata empiirilised mudelid modelleerimaks innovatsiooniallikate valikut mõjutavaid tegureid;
7. koostada ja hinnata empiirlised mudelid innovatsiooniallikate omavahelise asendatavuse uurimiseks;
8. analüüsitud mudelite baasil pakkuda välja poliitikasoovitusi.

Käesoleval doktoritööl on ka mitmed nii teoreetilist kui ka empiirilist laadi piirangud, mida peab arvestama tulemuste tõlgendamisel. Innovatsiooni–prptsessis kasutatavad teadmuse kategooriad ei ole täpselt piiritletavad, eksisteerivad teatud kattuvused, mida tuleb arvestada teoreetilise käsitluse rakendamisel empiirilises analüüsis. Ettevõttesiseste pidevate innovatsiooni–protsesside empiiriline hindamine toimub diskreetsete innovatsioonide toimumise või mittetoimumise kaudu, mis raskendab veidi tulemuste tõlgendamist ja ühendamist teoreetiliste käsitlustega.

Lisaks eeltoodule tugineb selline hindamine ettevõtetes läbi viidud küsitlusele, kus innovatiivset tegevust hinnatakse vastajate subjektiivse arvamuse põhjal (mis võib olla kallutatud ja sõltuda näiteks vastaja kompetentsusest aga ka organisatsiooni poliitikast). Selle probleemi vähendamiseks on võimaluse korral püütud käesolevas töös kontrollida teatud hinnanguid samaaegselt mitmete aspektide uurimisel erinevate küsimuste kaudu (eesmärgiga tuvastada vastuolusid), samuti on küsitlustulemusi kõrvutatud ettevõtete juhtidega tehtud intervjuudega.

Töö empiirilises osas ei ole kahjuks võimalik eristada teadmuse liikumise erinevaid kanaleid. Näiteks, teadmuse liikumine ettevõtete vahel võib toimuda lisaks ettevõtetevahelistele kontaktidele ka töötajate liikumise, samuti haridusasutuste ja ettevõtete vahel koolilõpetajate palkamise kaudu. Seda aspekti eraldi ei ole võimalik välja tuua kasutatud andmestike abil, lisanduva töötaja teadmus klassifitseeritakse käesolevas töös lihtsustatult ettevõttesiseste innovatsiooniallikate kategooriasse.

Lisaks ei ole andmestiku põhjal võimalik järeldusi teha teadmuse regionaalse liikumise kohta, mõningaid kaudseid hinnanguid on võimalik anda, kuid need piirduvad peamiselt kodumaiste/välismaiste allikate eristamisega, kuid ka seda ei ole tulenevalt andmete kogumise meetodite muutusest võimalik süstemaatiliselt läbi viia.

Empiirilised tulemused kehtivad uuritud ajaperioodi kohta, nende ektrapoleerimine võib olla problemaatiline, kuna vaatamata sellele, et üldine institutsionaalne keskkond muutub suhteliselt aeglaselt, võivad turult tulevad impulsid muuta olukorda märkimisväärselt, mis omakorda võib mõjutada teadmusallikate kasutamist. Vaatamata eeltoodule on siiski kasutatud poliitikasoovituste andmiseks empiiriliste tulemuste simulatsiooni, mille tõlgendamisel tuleb kinldasti eeltoodud piirangut arvestada.

Doktoritöö teoreetiline taust

Teadmust võib defineerida väga erinevalt – kui objekti, protsessi, meeleolu või ka võimet. Käesolevas uurimuses käsitletakse teadmust selle kõige laiemas tähenduses, mis hõlmab faktiteadmisi, oskusi ja kogemusi. Tavaliselt vaadeldakse teadmuse kujunemist hierarhilise protsessina, mis saab alguse andmetest, mis sobivalt organiseerituna kujundavad informatsiooni, mis omakorda absorbeerituna, tõlgendatuna ja kasutatuna muutub teadmuseks (Cooley, 1987). Selleks, et paremini mõista innovatsioonprotsessides kasutatavat teadmust, on siiskivajalik selle täpsem kategoriseerimine. Tavaliselt on evolutsioonilise majandusteooria autorid kasutavad üldisemaid teadmuse kategooriaid, mis põhinevad teadmuse ülekantavusel ühelt agendilt teisele (nt Polanyi, 1966; Nelson, Winter, 1982; Dosi, 1988), mõnikord arvestatakse seejuures ka sotsiaalseid aspekte nagu agentide jõuvahekordi (Fleck, Tierney, 1991).

Lisaks üldistele teadmuse kategooriatele on mõned autorid välja toonud detailsemad, objekti alusel kategoriseeritud teadmuse tüübid, mille kasutamist innovatsiooniprotsessides on ka empiiriliselt kontrollitud (Gibbons, Johnston, 1974; Vincenti, 1990 ja Faulkner et al. 1995). Sellisteks teadmuse kategooriateks on näiteks loodusega seotud teadmus (loodus- ja inseneriteaduste teooriad; materjalide omadused); disainiga seotud teadmus (disaini kriteeriumid ja rakendusvaldkonnad, disaini kontseptsioonid, disaini instrumentaarium; disainialane kompetents ja praktiline kogemus); eksperimentaalse uurimis- ja arendustööga seotud teadmus (eksperimendi- ja testiprotseduurid, uurimisinstrumentaarium, uurimiskompetents, eksperimentide ja testide tulemusena saadud andmed); lõpptoodanguga seotud teadmus (uued tooteideed, operatsiooniprintsiibid, tootmisalane kompetents); teadmusega seotud (materjalide ja komponentide olemasolu ja kättesaadavus; spetsiifiliste teenuste ja seadmete olemasolu ja kättesaadavus; teadmuse paiknemine).

Empiirilised uuringud näitavad, et iga konkreetne teadmuse kategooria on ettevõtete jaoks kättesaadav kindlast peamisest teadmuse allikast, mis tähendab, et iga teadmuse allikas kannab endas spetsiifilist teadmust (Gibbons, Johnston, 1974) ning seega allikate vaheline asendatavus on suhteliselt madal. Kõige olulisemateks teadmuse allikateks ettevõtete innovatsiooniprotsessides on ettevõttesisesed allikad (ettevõtte töötajate ja juhtide kompetents), kuid sõltuvalt teadmuse kategooriast võivad mõned ettevõttevälised teadmusallikad olla vägagi olulised (näiteks kui on vaja teadmisi kindlat tüüpi materjalide, seadmete või teenuste kohta, osutuvad ettevõttevälised teadmusallikad väga olulisteks).

Ettevõttesiseste teadmusallikate olulisus on kirjanduses välja toodud kolme peamise põhjuse kaudu:

1. Selleks, et ära tunda, selekteerida, absorbeerida ja kasutada ettevõttevälist teadmust, on vajalik ettevõttesisene kompetents (nn Coheni ja Levinthali (1989) absorbeerimisvõime argument);
2. Teadmuse omandamine ja loomine on kumulatiivne ettevõtte tasandil (nn rajasõltuvuse argument). See põhjus on eriti oluline valdkondades, kus vajatakse rohkem kogemusele tuginevat teadmust, mis tuleneb ettevõtte võimekusest ja ettevõtte püüdlustest;
3. Kuna spetsiifiline teadmus innovatsiooniprotsessides (eriti uurimis- ja arendustegevuses) on sageli väga oluline ja sageli kontsentreeritud konkreetsesse ettevõttesse, siis seda ei ole võimalik väljastpoolt hankida (Pavitt, 1984; Dosi, 1988).

Tarbijaid või kliente kasutatakse sageli innovatsiooniallikana saamaks paremat turualast teavet eesmärgiga alandada riske ja kulusid eriti just uudsete või väga keeruliste toodete puhul. Tavaliselt kasutatakse tarbijatelt saadavat teadmust just tooteinnovatsioonide läbiviimiseks, kuid mõned juhtumiuuringud näitavad, et tarbijatel on oma roll ka protsessiinnovatsioonides (samas ei ole need tulemused leidnud kinnitust tööstusharu tasandil). Ettevõtte suurus ei ole tarbijatelt tuleva teadmuse absorbeerimisel nii oluline kui teistest allikatest saadava teadmuse puhul, mis tähendab, et tarbijaid võib pidada oluliseks teadmusallikas väike- ja keskmise suurusega ettevõtete jaoks.

Seadmete, pooltoodete ja materjalide tarnijad ei ole olulised mitte ainult protsessiinnovatsioonides kasutatava teadmuse saamiseks, vaid samuti uute toodete ja teenuste loomisel ning disainiprotsessides. Seejuures on leitud, et organisatsioonilised barjäärid ja sobiva tööjõu puudumine ettevõttes mõjutavad koostööd tarnijate või pakkujatega (sarnaselt tarbijatega), kuid finantsbarjäärid on pakkujate puhul vähemolulised (erinevalt tarbijatest). Mõnedes uuringutes on leitud, et eksportivatel ettevõtetel on suurem surve tehnoloogiate arendamiseks ning seetõttu teevad just rahvusvahelistunud ettevõtted pakkujatega tihedamat koostööd infovahetusel.

Konkurente kasutatakse teadmusallikana samuti kulude ja riskide alandamiseks innovatsioonialases tegevuses, kuid siiski on konkurentidega koostöö veidi erinev, kuna see on tavaliselt mitteformaalne ja tugineb rohkem personaalsetele kontaktidele (siiski eriti just haruliitude kaudu toimub ka lepinguline uurimis- ja arendusalane koostöö). Siiski ei ole täpselt selge, missugust teadmust vahetatakse – kas tehnoloogilist, disainialast, turualast või kõike eelnimetatut. Kirjanduses on leitud, et kontsernidesse kuuluvad ettevõtted sageli konkurentidega koostööd ei tee ja teadmuse vahetamist ei toimu, kuna eelistatakse kontsernisiseseid allikaid. Erinevalt konkurentidest on konsultantide kasutamine lepinguline ja seega ka kallis meetod ettevõtte sees puudu jääva teadmuse hankimiseks väljastpoolt.

Ülikoolid ja teadusasutused mängivad ettevõtete innovatsiooniprotsessides olulist rolli peamiselt kahte tüüpi teadmuse kaudu (uus teadmus teaduse ja tehnika spetsiifilistes valdkondades; praktiline abi tehnoloogiliste probleemide lahendamisel, instrumentaarium) (Faulkner et al. 1995). Ülikoolide kasutamine teadmusallikana sõltub paljudest teguritest, näiteks haruspetsiifilistest (kas tootearendus on rohkem teadusepõhine või pigem pakkujate ja tarbijate poolt juhitav); riigi teadussüsteemi poolsetest teguritest (kas vastav ülikooliteadmus on konkreetses riigis kättesaadav ja kaasaegne); tehnoloogiaspetsiifilistest teguritest (vastava tehnoloogiavaldkonna vanus, küpsus ja dünaamika) ning ettevõttespetsiifilistest teguritest (võime võrgustike kaudu teadmust hankida, ettevõtte avatus uutele töötajatele, uutele ideedele jne).

Erinevate tööstusharude tehnoloogiline areng on väga erinev nii selle tõukejõudude kui ka arengutrajektooride mõttes (ülevaadet tehnoloogilise arengu ja innovatsiooni sektoraalsetest eripäradest vt nt Pavitt, 1984). Puidutööstuse eripäraks on asjaolu, et ettevõtted neis harudes rakendavad küll kõrgtehnoloogiaid ja on innovatiivsed, kuid samal ajal on neis harudes väga madalad teadus- ja arenduskulude tasemed (Hirsch-Kreinsen et al.. 2003; Laestadius 1998a; Laestadius 1998b), mistõttu nad klassifitseeritakse enamasti madala tehnoloogilise tasemega harude hulka.

Kõige olulisemaks on Eesti puidusektori jaoks vaadeldaval perioodil olnud tehnoloogilised innovatsioonid. Puidul baseeruvate tööstusharude põhitehnoloogiad ja –protsessid ei ole viimastel aastatel drastiliselt muutunud, uuendused on peamiselt seotud uute informatsiooni- ja kommunikatsioonitehnoloogiatel (IKT) baseeruvate lahendustega puidu töötlemises ja logistikas, laienenud keemiatehnoloogiate kasutamisega puidu struktuuri analüüsil ning samuti puidu vastupidavuse tõstmisel, lisaks kasutatakse järjest rohkem uusi puidu kombinatsioone teiste materjalidega nt ehituses. Seesugused järk-järgulised muutused protsessides on siiski märgatavalt parandanud lõpptoodangu omadusi. Eeltoodud üldised tehnoloogia muutumise protsessid on toimunud kiiremini Eesti sarnastes üleminekuriikides viimase 15 aasta jooksul. Eesti puidusektoris on toimunud väga kiire tehnoloogiline areng just viimastel aastatel, kus peamisteks muutusteks on modernsete mehhaniseeritud raiesüsteemide kasutuselevõtmine; arenenud saetööstuse, puitplaatide ning paberitööstuse tehnoloogia; muudatused puit(element)majade ehituses ning akna- ja uksetootmise tehnoloogiates, samuti mööblitööstuses. Nende muutuste taga on eelkõige eksportnõudlus, samuti on paljuski tehnoloogiline areng osutunud võimalikuks otseste välisinvesteeringute tõttu.

Uurimismetoodika ja kasutatavad andmed

Käesoleva doktoritöö empiirilise andmestiku moodustavad nii statistilised andmebaasid kui ka intervjuud ettevõtjatega. Töös on kasutatud Eesti Statistikaameti poolt läbi viidud kahe innovatsiooniuuringu (Innovatiivne tegevus Eesti ettevõtetes 1998–2000 ja Innovatiivne tegevus Eesti ettevõtetes 2002–2004) andmeid. Mõlemad uuringud on läbi viidud vastavalt Euroopa Komisjoni ja Eurostati poolt ühtlustatud metoodikale (*Community Innovation Survey Version 3 and 4*). Nende andmebaasidega on kaetud töötajate arvu järgi vastavalt 41% ja 57% puidusektori ettevõtetest.

Lisaks eeltoodule viis autor 2006. aastal läbi 19 intervjuud puidusektori ettevõtete juhtidega. Esialgse valimi koostamisel valiti 30 seejuures suuremat puidusektori ettevõtet eeldusel, et need ettevõtted mõjutavad sektori innovatiivset tegevust märkimisväärselt, samuti on suuremad ettevõtted kõige tõenäolisemad vastava valdkonna klastri arendajad. Sealjuures jälgiti esinduslikkust nii regionaalse jaotuse kui ka allharude struktuuri lõikes (allharudena vaadeldi järgmisi tööstusharusid: metsandus (02), puidutöötlemine (20), paberi- ja tselluloositööstus (21), mööblitööstus (36.1)). Siinkohal tuleb kohe märkida, et mitmed valimisse kaasatud ettevõtted kuuluvad vaid tinglikult sellise jaotuse alla, kuna kuuluvad statistiliselt puidu hulgimüüjate (51) või nt muusikariistade tootjate (36.3) kategooria alla. Samuti kuuluvad paberi- ja tselluloositööstuse alla papist pakendite tootjad, mida võib pidada ka pakenditööstuse alla kuuluvaks. Nende intervjuudega kaeti töötajate arvu järgi 13% puidusektori ettevõtetest. Lisaks kasutati ka varasemaid kolleegide poolt aastal 2003 läbi viidud intervjuusid, mis katsid 4% puidusektori ettevõtetest. Kogu andmestik on detailsemalt kirjeldatud töö alapunktis 2.1.1.

Alapunktis 2.2.1 formuleeriti üheksa uurimishüpoteesi teadmusallikate kasutamise kohta innovatsiooniprotsessides, teadmusallikate kasutamist mõjutavate tegurite ning teadmusallikate omavahelise asendatavuse kohta. Nende hüpoteeside kontrollimine toimus ökonomeetriliste mudelite abil kolmes etapis, seejuures kasutati intervjuude tulemusi nii hüpoteeside püstitamisel kui ka tõlgendamisel.

Esmalt koostati binaarsed logistilise regressiooni mudelid (*binary logictic models*) määramaks innovatsiooniallikate (mis olid erinevates mudelites sõltumatuteks muutujateks) kasutamise mõju erinevas innovatsiooniprotsessi etappides (erinevates mudelites olid sõltuvateks muutujateks erinevad innovatsiooniprotsessi etapid). Lisaks innovatsiooniallikatele sisestati mudelitesse ka kontrollmuutujad ettevõtte karakteristikute, samuti erinevat tüüpi teadmuse hankimiseks tehtud rahaliste kulutuste kohta.

Seejärel uuriti samuti logistilise regressiooni mudelite abil erinevaid innovatsiooniallikaid (sõltuvad muutujad) mõjutavaid tegureid (sõltumatud muutujad), regressiooni sisestati nii ettevõtte karakteristikud, koostööd peegeldavad tegurid kui ka takistavad tegurid.

Viimaks testiti ühefaktorilise dispersioonianalüüsi (*ANOVA – univariate analysis of variance*) abil erinevate teadmusallikate kooskasutust innovatsiooniprotsessides määramaks vastastikust täiendavust või asendatavust.

Töös püstitatud uurimishüpoteesid ja nende analüüsi tulemused

Käesolevas doktoritöös on püstitatud üheksa uurimishüpoteesi innovatsiooniallikate kasutamise, seda mõjutavate tegurite ning nende omavahelise asendatavuse kohta. Töö eesmärki silmas pidades aitavad kõik püstitatud hüpoteesid selgitada erinevate teadmusallikate olulisust ettevõtete innovatsiooniprotsessis. Alljärgnevalt on toodud hüpoteesid koos empiirilise analüüsi tulemustega Eesti puidusektori näitel.

H1: Ettevõttesisesed innovatsiooniallikad on peamised teadmuse allikad, mida ettevõtted kasutavad kõigis erinevates innovatsiooniprotsessi etappides
Esimese hüpoteesi testimisel kasutati kümne mudeli hindamist ajaperioodi 2002–2004 kohta, mille tulemusena pooltel juhtudest saadi hüpoteesi toetavad tulemused. Seega ei ole võimalik nende mudelite baasil hüpoteesi veenvalt ümber lükata. Probleemiks on siinkohal kindlasti asjaolu, et hinnatavates mudelites on ettevõttesisesed ja kontsernisisesed teadmusallikad koondatud andmebaasis ühe muutuja alla. Kuna kontsernisiseste allikate olulisus innovatsiooniprotsessis on oluliselt madalam, hindab kasutatud indikaator ka ettevõttesiseste

teadmusallikate rolli tegelikust madalamaks. Samas saadi toetavad tulemused Eesti puidusektori jaoks kõige olulisemate innovatsioonide kohta (toote ja tootmisprotsesside innovatsioonid).

H2: Võimekamad ettevõtted kasutavad rohkem erinevaid ettevõtteväliseid teadmusallikaid

Teise hüpoteesi testimine toimus samuti mitmete mudelite baasil ning hüpotees leidis kinnitust enamiku oluliste teadmusallikate puhul – tarbijad ja tarnijad. Mõnesid teadmusallikaid näiteks nagu ülikoole kasutati ettevõtete poolt suhteliselt vähe ning seega oli ka ettevõtete võimekuse erinevuste väljatoomine nende puhul raskendatud). Seega võib väita, et teadmuse kasutamise vallas võimekamad ettevõtted (ettevõtted, kellel oli juhuslik või pidev uurimis- ja arendustegevus või kes kulutasid suhteliselt rohkem personali koolitusele) kasutasid suurema tõnäosusega ka ettevõtteväliseid teadmusallikaid oma innovatsiooniprotsesside läbiviimiseks.

H3: Tarbijaid kasutatakse teadmusallikana tooteinnovatsioonide läbiviimiseks

Kolmas hüpotees leidis kinnitust tooteinnovatsioonide mudelis, mistõttu võib väita, et tooteinnovatsioonide väljatöötamiseks kasutavad puidusektori ettevõtted tarbijatelt saadavat teadmust. Samas tuleb märkida, et lisaks tarbijatele kasutatakse tooteinnovatsioonide läbiviimiseks ka konkurentidelt ning konverentsidelt saadavat informatsiooni. Ettevõtjate intervjuudest selgub, et kuna turustamiseks kasutatakse sageli vahendajaid, ei jõua tarbijatelt tulev informatsioon sageli tootva ettevõtteni. Seetõttu kasutatakse ka konkurente (kuna Eesti ettevõtted eriti just eksportturgudel ei ole oma väiksuse või erinevate niššide tõttu teravalt konkureerivad) ning üldisema teadmusallikana ka konverentse.

H4: Tarnijaid kasutatakse peamise teadmusallikana tehnoloogiliste protsessiinnovatsioonide läbiviimisel

Neljas hüpotees leidis kinnitust tehnoloogilist protsessiinnovatsiooni analüüsivas mudelis, kuid lisaks ka veel tootmise abiprotsesse ja tööde organiseerimist kirjeldavates mudelites, mis võimaldab väita, et Eesti puiduettevõtetes tuginevad seesugused innovatsiooniprotsessid tarnijate teadmusele. Kuigi hüpotees oli kirjanduse ja intervjuude põhjal püstitatud kitsamalt, saab väita, et tarnijate roll protsessiinnovatsioonis on oluliselt laiem, siiski tuleks seda täiendavalt uurida just organisatsiooniliste innovatsioonide puhul.

H5: Kontsernidesse kuuluvad ettevõtted kasutavad innovatsioonide läbiviimisel teadmusallikana suhteliselt vähem konkurente

Viies hüpotees leidis kinnitust varasemat perioodi kajastavas mudelis, kuid lükati kindlalt ümber hilisema perioodi kahes mudelis, millest üks käsitles konkurente ja teine haruliite innovatsiooniallikatena. Kahjuks ei ole varasemat perioodi kajastavaid ettevõtjate arvamusi võimalik tõlgendada. Hilisema perioodi intervjuusid peegeldab kõige paremini ühe ettevõtja arvamus „*Rootsi metsatööstuskontsernid teevad koostööd omavahel Eestis kogu selle kokteili sees, kus /Eesti ettevõtted/ seda kokteili segavad nt logistikas, kaubandusvoogude suunamises /…/, kasvõi aeg-ajalt hinna korrigeerimises või ühises alustamises, et midagi muutuks aktiivsemaks. Aga seda nad ei tee kungi Rootsis – nende autod kunagi ei vea teise kontserni puitu näiteks, seda ei tehta. See on haruldane ja see on imporditud Eesti firmade tütarettevõtete kaudu ka teistesse Balti riikidesse*“. Eeltoodu viitab tõsiasjale, et ka välismaiste kontsernide tütarettevõtted on hakanud aktiivsemalt kohalikes koostööprotsessides (sh teadmusvahetuses) osalema ja seda nii haruliitude kui ka ettevõtete vaheliste otseste koostöövormide kaudu.

H6: Finantsbarjääride olemasolu ettevõtete innovatiivses tegevuses takistab väliste teadmusallikate kasutamist

Selle hüpoteesi testimiseks kasutati mitmeid erinevaid perioode ja erinevaid teadmusallikaid analüüsivaid mudeleid. Nende põhjal saadud tulemused ei ole ühesed. Nimelt selgub, et ettevõttesiseste finantseerimisallikate puudus alandab tõenäosusi kasutada ettevõtteväliseid teadmusallikaid, samas kui ettevõtteväliste finantseerimisallikate puudus suurendab tõenäosust kasutada ettevõtteväliseid teadmusallikaid. Intervjuudest selgub, et mõlemad finantseerimisallikad on omavahel seotud, kuna edukate majandusnäitajatega ettevõtetel ei ole probleeme hankida ettevõttevälist finantseerimist oma innovatsiooniprotsesside teostamiseks. Samas ei ole majandusraskustes vaevleval ettevõttel võimalik väliseid finantseerimisallikaid kasutada. Seetõttu võib pigem arvata, et tõsised finantsbarjäärid takistavad teadmuse hankimist väljastpoolt ettevõtet.

H7: Teadmusega seotud barjääride olemasolu ettevõtete innovatiivseks tegevuseks ergutab väliste teadmusallikate kasutamist

Teadmusega seotud barjääride hindamiseks kasutati mitmeid indikaatoreid ja analoogiliselt finantsbarjääridega mitmeid mudeleid, mida hinnati erinevatel ajaperioodidel. Teadmusega seotud barjäärideks loeti ettevõtetes organisatsioonilised barjäärid, vajatava kvalifikatsiooniga töötajate nappus, turu- ja tehnoloogiaalase teabe pudulikkus ning samuti raskused partnerite leidmiseks innovatsiooniprotsesside läbiviimisel. Kõik eeltoodud teadmusega seotud barjäärid suurendasid tõenäosust väliste innovatsiooniallikate kasutamisel (erinevates mudelites küll erineval määral), erandiks osutus partnerite leidmise probleem, mis alandas tõenäosust kasutada väliseid teadmusallikaid. Viimast võib pidada oodatavaks tulemuseks ka intervjuude analüüsi põhjal. Seega ei saa käesolevate andmete abil seitsmendat hüpoteesi ümber lükata.

H8: Ettevõttesisesed teadmusallikad täiendavad ettevõtteväliseid teadmusallikaid

Kaheksas hüpotees leidis kinnitust enamike väliste teadmusallikate puhul. Kahtlus tekkis konsultantide ja konverentside puhul, kuid kuna erinevused osutusid ebaolulisteks, et saa nende põhjal hüpoteesi ümber lükata.

H9: Ettevõttevälised teadmusallikad täiendavad üksteist vastastikku

Hüpoteesi testimiseks kasutati kaheksat mudelit ning tulemused näitavad, et enamik ettevõttevälistest teadmusallikatest on omavahel üksteist täiendavad. Samas leiti analüüsi käigus ettevõtete poolt vähem kasutatud allikate puhul vastastikust asendamist (mis osutus ka statistiliselt oluliseks). Sellisteks teadmusallikateks osutusid ülikoolid, teadusasutused, konsultandid ja konverentsid, mille omavaheline asendatavus võib näidata nii sarnase teadmuse pakkumist nende allikate poolt kui ka asjaolu, et mõned allikad (nt ülikoolid ja teadusasutused) on puiduvaldkonnas Eestis nõrgalt esindatud ning ettevõtted on sunnitud otsima vajatavale teadmusele alternatiivseid allikaid.

Kui võtta kokku nii hüpoteeside kontrollimisel saadu kui ka mudelite hindamisest saadud kõrvaltulemused (sh poliitikasimulatsioonid), siis võib öelda, et Eesti puidusektori innovatsioonid tulenevad peamiselt ettevõtte siseste või ka väliste teadmusallikate kasutamisest ja ei ole seotud rahaliste investeeringutega teadus- ja arendustegevusse. Seadmete ja materjalide tarnijad on üks olulisemaid ettevõtteväliseid innovatsiooniteadmuse allikaid, mida puidusektori ettevõtted kasutavad erinevate protsesside uuendamiseks (tehnoloogilised, organisatsioonilised protsessid, disain). Need allikad on eriti olulised just nende ettevõtete puhul, kes tunnetavad tehnoloogilise teabe vajakajäämist innovatsioonide väljatöötamisel. Tarbijaid kasutatakse tooteinnovatsioonide väljatöötamiseks ettevõtetes, kellel jääb vajaka turualasest teabest. Konkurente ja haruliitusid kasutatakse peamiselt toote- ja turundusalaste innovatsioonide läbiviimiseks. Analüüsitulemused näitavad, et välisosalusega ettevõtted tihendavad järjest rohkem oma innovatsioonialast koostööd kohalike ettevõtetega (nii haruliitude kui ka konkurentidevahelise mitteformaalse teabevahetuse kaudu).

Mõjuteguritest võib lisaks finants- ja teadmmusebarjääridele doktoritöö põhjal välja tuua peamise riigispetsiifilise teguri: haridus- ja teadussüsteemi mittevastavus majanduse spetsialiseerumisele. See väljendub antud kontekstis asjaolus, et ettevõtted ei kasuta oma tehnoloogiliste innovatsioonide puhul ei ülikoole ega ka teadusasutusi innovatsiooniallikana – põhjuseks asjaolu, et selline teadmus Eesti ülikoolides puudub. Samas kasutavad ettevõtted ülikoole nt turundusalaste innovatsioonide loomisel, milleks leidub kompetentsi mitmes ülikoolis. Erinevalt erasektori teadmusallikatest on avaliku sektori teadmusallikad omavahel asendatavad ettevõtete innovatsiooniprotsessides, mis näitab pakutava teadmuse suhtelist sarnasust ja ka üldisust. Kokkuvõttes võib järeldada, et olulisemad innovatsioonid töötatakse välja Eesti puidusektoris ettevõtete endi ressurssidele lisaks eelkõige äripartnerite toel, avalik sektor ei toeta innovatsioonide loomist selles sektoris.

Soovitusi tulevasteks uuringuteks

Tulevased uuringud käesoleva doktoritöö valdkonnas võiksid keskenduda järgmistele aspektidele. Esmalt tuleks detailsemalt uurida teadmuse kasutamist nii puidusektoris (kaasates uurimisobjektina näiteks teisi oluliselt puidusektoriga seotud riike nagu Soome, Rootsi, Austria), kuid samuti ka teisi sektoreid eesmärgiga arendada innovatsiooniteadmuse teaduslikku käsitlust. Eriti oluline on arendada seda käsitlust edasi traditsioonilistes harudes mõistmaks paremini nende seotust kõrgtehnoloogiliste harude innovatsioonidega, samuti selleks, et kujundada poliitikaid, mis toetavad teadmusvahetuse kaudu üldiselt innovatsiooniprotsesse. Hetkel on näiteks erinevate innovatsiooniallikate vastastikune asendatavus või täiendavus vaid väga põgusalt kirjanduses kajastatud. Uurimist vajaks innovatsiooniallikate samaaegne sünergeetiline kasutamine innovatsiooniprotsessides. Lisaks eeltoodule aitaks erinevates riikides sarnaste sektorite uurimine parandada ka arusaamist institutsioonidest, mis teadmusvahetust ergutavad või pidurdavad.

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