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TÕNIS TÄNAV

Dynamics of firm innovation strategies: relationship with public sector support

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Dynamics of firm innovation strategies: relationship with public sector support

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Press

School of Economics and Business Administration, University of Tartu, Estonia

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4. Ukrainski, K., Kanep, H., Timpmann, K., **Tänav, T.** (2015) TIPS uuring 2.3. Eesti teaduse rahastamise instrumentide koostoime analüüs.

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2. **Tänav, T.** (2019) Relationship Between Public Support to Firms and Dynamics of Firm Innovation Strategies. Atlanta Conference on Science and Innovation Policy, Atlanta, USA. October 14-16, 2019.
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1. INTRODUCTION

Innovation has been on the forefront of public policy as a panacea for economic ills for a long time. In Europe, governments on the EU, Member State and local municipality levels intervene in private businesses with public money. The aim is to create economic growth by accelerating the creation and diffusion of innovation with taxpayer contributions. In turn, the redistribution of funds and its efficacy is of considerable interest to a wider audience. Discussions on specific projects can often be found even in newspapers.[1]

The justification for intervening through public policy to enhance the innovative capabilities of firms has been studied extensively. Firms lack optimal conditions to appropriate their own research and development (R&D) efforts, leading to limited investments and social welfare loss (Arrow, 1962; Nelson, 1959). Policy should also address the distribution of R&D costs within and between firms (Mowery, 1983), the learning and knowledge transfer aspects of the innovation process (Nelson and Winter, 1982), and the interaction between institutions (Lundvall, 2010). Over the past half century, science, technology and innovation (STI) policies have widened in scope into multiple policy realms and have been used to develope more sophisticated policy instruments (Borrás, 2009; Laranja et al., 2008; Schot and Steinmueller, 2018). Consecutively, the possible effects of policy instruments are more intertwined, interacting and conflicting, suggesting a need to evaluate the whole "policy mix" concurrently (Flanagan et al., 2011; Howlett, 2005; Howlett et al., 2015; Magro and Wilson, 2013).

Firms seek innovations for competitive advantages — successful new products and services that give them an edge on the market. Firms' choices for creating and executing their innovation strategies are influenced by a mix of internal and external factors (Rothaermel, 2017). Capabilities and resources developed within the firm create hard-to-copy advantages over competitors (Prahalad and Hamel, 1990; Teece et al., 1997). Differentiation as a strategy for competitive advantage further emphasises this attitude (Caves and Porter, 1977). Even within industries there are subgroups with unique inputs and outputs that affect the innovation process (Lee, 2003). Firms are also bound by the barriers, constraints and enablers of any sector in which they operate (Nelson and Winter, 1977, 1982; Winter, 1984). Path dependencies in sectors are distinguished by potential for creating and diffusing innovations in technological regimes (Dosi, 1982, 1988b; Nelson and Winter,

[1] The public seems to be especially fond of stories which include deception, misuse and fraud. Besides their entertainment value, they are a wonderful indicator that the public still cares about where tax contributions are spent.

1977). Major commonalities of innovation strategies have been identified on the sectoral level (Bogliacino and Pianta, 2016; Castellacci, 2008; Pavitt, 1984), leading researchers to search for similar behavioural traits on the firm level (Frenz and Lambert, 2012; Hollenstein, 2003; Leiponen and Drejer, 2007).

However, research to date has not fully addressed the question of whether firms change their innovation strategies when they receive public support for executing certain innovation activities (Chapman and Hewitt-Dundas, 2015; Clarysse et al., 2009; Georghiou and Clarysse, 2006). Despite excellent work in establishing empirical firm-level groupings of innovation strategies (Battisti and Stoneman, 2010; Camacho and Rodriguez, 2008; De Jong, Vanhaverbeke, et al., 2008; Frenz and Lambert, 2012; Hollenstein, 2003, 2018; Jensen et al., 2007; Leiponen and Drejer, 2007; Marsili and Verspagen, 2002; Pavitt, 1984; Pavitt et al., 1989; Srholec and Verspagen, 2008) as well as decades of research on the impacts of public support of innovative behaviour (Dodgson and Bessant, 1996; Martin, 2016; Petrin, 2018; Salter and Martin, 2001), researchers investigating the effects of STI policy instruments have not fully explored the effects policy instruments on the dynamics of innovation strategies within the firm.

I will fill a part of this gap by connecting these two themes. The aim of this thesis is to estimate the possible effects of STI policy instruments on firm innovation strategy. Several objectives have been set to achieve this aim:

- To analyse firm innovation strategies
- To describe the dynamics of firm innovation strategies
- To analyse public policy instruments for promoting innovation in firms and develop a taxonomy based on the Estonian example
- To empirically estimate the relationship between innovation outputs and policy instruments
- To empirically estimate the relationship between policy instruments and dynamics of firm innovation strategies

All these objectives have details, sub-objectives, caveats and further relevant explanations. These will be in the corresponding chapters, which explain the main questions for each chapter and estimation.

The rest of the introduction briefly introduces the main topics deemed relevant to investigate the relationship between policy instruments and innovation strategies. These main topics are introduced in the following order: (i) the rationale for public intervention with innovation policy; (ii) the problems with current taxonomies of STI policy instruments; (iii) the strategic management view of the innovation process; (iv) the technological regimes and trajectories view of the innovation process; (v) the meaning of innovation, entrepreneurship and innovation strategies in the context of this thesis; (vi) a brief description of data used in this thesis; (vii) a brief description of methods used in this thesis; (viii) the contribution of this thesis; and (ix) a brief description of the structure of this thesis.

The national innovation system framework (Lundvall, 2010) is the most relevant for contextualising innovation policy and its instruments in this thesis. It emphasises the links between different actors in the innovation system, such as firms, universities, financial system, etc. It also emphasises framework conditions, such as attitude towards entrepreneurship, business culture, legal system, taxation and incentives, etc. (Kuhlmann and Arnold, 2001). The national innovation system framework is a step forward from the earlier linear innovation process models, where the main aim of public policy was only to directly finance R&D (Schot and Steinmueller, 2018).

The next probable phase of innovation policy, dealing more with transformative socio-technological changes, is not currently widespread enough to be relevant here (OECD, 2015; Schot and Steinmueller, 2018). Mission-based policies advocated by Mazzucato (2015, 2018) and the general increase of state interference and decision-making in innovation policy is currently very popular in the EU discourse. Dubbed the innovation policy 3.0, it will probably have a large effect on the design of policy instruments in the next decade. Especially in large-scale projects funded by the European Comission in the new framework programme Horizon Europe. However, these concepts are just taking off. Chapter 3 describes the innovation policy in Estonia between 2000 and 2012, which is mainly based on ideas from the second generation of innovation policies. Due to this, there will not be an in-debth analysis of the possible new era, but more emphasis on what has been currently done.

In the national innovation system thinking, the justifications for public intervention have become wider than just financing R&D efforts (Laranja et al., 2008). Besides appropriability of R&D outcomes, rationales for intervention include managerial capabilities and failures in cooperation, learning and institutions. New rationales demand a much wider set of instruments. Regulations, economic transfers and soft instruments in various activities are recommended for policymakers (Borrás and Edquist, 2013). These activities include, but are not limited to, incubation services, consultancies, R&D provision, competence building, standardisation and creation of new support organisations (Borrás and Edquist, 2013). The scope of innovation policy is thus to increase the overall innovative performance of a country, which, unsurprisingly, cannot be done with a single policy instrument (Lundvall and Borrás, 2006). Technology and science policy are therefore subsets of the wider innovation policy.

Current taxonomies of STI policy instruments are too narrow to encompass wider sets of policy instruments. There are several reasons for this. First, innovation policy itself is too wide in scope, as relevant lists of instruments would be hundreds of items long. Second, there is positive discrimination towards R&D instruments, e.g. Edler and Georghiou (2007) and Izsak, Markianidou, et al. (2013), leaving out other simultaneously supported actions. Third, there are differences between countries, so policy instruments are generally somewhat tailored to local conditions. Nevertheless, there is evidence that homogeneity of innovation policy instruments can be seen in the EU (Veugelers, 2015). Finally, taxonomies used in empirical estimations should encompass the policy mix appropriately in order to highlight possible effects (Flanagan et al., 2011).

Due to these reasons, I develop a new taxonomy of direct public support instruments based on policy instruments which have been available in Estonia. This taxonomy is the basis for empirical analysis in later chapters as well. The relevant discussion, methods, results and descriptions are in Chapter 3.

The innovation process within the firm has been extensively developed during the last century, ever since Vannevar Bush's (1945) call to accelerate the development of new products through the public support of R&D. I will introduce two major literature streams in this thesis, the *strategic management* view of the innovation process and the *technological regimes* approach to the innovation process. In many ways, these literature streams emphasise contrasting views of the innovation process and choices for strategy creation. The strategic management view emphasises firms' own ability to take actions and create its own path. The technological regime view emphasises the boundaries of firms' technological level and sector — how firms are not free to search in all directions for innovations. Both views are necessary for understanding firm choice in the creation of innovation strategies.

The strategic management literature emphasises within firm capabilities and actions, their planning and execution. The main catalyst is the firm itself, searching for strategies that give long-term competitive advantages over competitors. Firms rely on resources and routines which are difficult to imitate (Wernerfelt, 1984). Furthermore, firms need to update these resources and routines to match changing environments (Teece et al., 1997). In effect, innovation strategies are born from firms' own ideas of what could give them a competitive edge and how these should be executed. In Chapter 2.4, the internal capabilities of firms and choices for constructing innovation strategies are described.

Another theory explaining the choices of firms while creating innovations is the technological regimes and trajectories approach. Technological regimes describe technological development paths for any sector in which firms operate (Nelson and Winter, 1977, 1982; Winter, 1984). The major attributes of technological regimes are the potential opportunities for innovation, the appropriability conditions in a given regime, the complexity of the knowledge base needed for innovative activities and the cumulativeness of innovations. For a firm operating within a technological regime, the process of innovation is path dependent. This path dependency is called a natural trajectory or technological trajectory (Dosi, 1982, 1988b; Nelson and Winter, 1977). A common understanding within this regime-trajectory framework is that industrial sectors share homogeneous characteristics, i.e. firms operating in the same sector have common technological trajectories (Castellacci, 2008; Pavitt, 1984; Pavitt et al., 1989). The expectation in this view is that firms are homogeneous in their innovation strategies within sectors of economic activities, and these strategies evolve slowly over time. Technological trajectories are therefore major external influencers of innovation strategies. How technological trajectories force path dependencies on firm innovation strategies is described in Chapter 2.1.

Innovation in this thesis is defined in a similar manner as in the Oslo Manual (2005), following from original Schumpeter contributions whereby innovation should include commercialisation and novelty (Schumpeter, 1934, 1942). Four main types of innovation are covered in this thesis: new product, new process, organisational and marketing innovation. A more general definition to briefly describe them all would be: an innovation is the market introduction of a new or significantly improved [good, service, process, etc.] with respect to its capabilities (adapted from OECD, 2005, p. 48-52). This broad definition is the basis for the Community Innovation Survey (CIS) as well, the most widespread innovation survey and data collection in Europe. CIS data is used for empirical analysis in this thesis. A full description of the definitions of different types of innovation, their caveats and strengths is in Chapter 4.1.

The study of firms, entrepreneurship and the innovation process has been central to modern economics. Even though Schumpeter has had a dominant influence on the current academic discourse, the roles and assumptions about entrepreneurship and entrepreneurs are varied (Hébert and Link, 2006).

The Oslo Manual (2005)[2] has been construed with the Schumpeterian entrepreneur in mind. In this line of thought, entrepreneurship is innovation. Entrepreneurs are not just capital owners, although they might be, nor are they managers akin to superintendents, overseers with no wish for development. Entrepreneurs are people who manage firms to create new combinations in production (Schumpeter, 1934). In addition, entrepreneurs require leadership and keenness to act upon knowledge. As Schumpeter (1934, p. 88) observed, inventions not carried out in practice are

[2] There is a newer version of the Oslo Manual (2019) also available. However, all the data and policies analysed in this thesis are more in-line with the previous version, therefore examples are from there.

economically irrelevant. Thus, the role of entrepreneurs is to use existing or new knowledge in new combinations to give them the edge on the marketplace.

The Schumpeterian perspective on economic growth postulates that it can come from competitive forces, new firms, ideas and innovations driving out the old (Schumpeter, 1934) — a competitive destruction of products and services that were once good enough but are now second best. On a macro level, the economy grows because new ideas and technology has been introduced to the market; on a micro level, firms seek advantages over their competitors. Endogenous growth models have reached similar conclusions on the macro level, where new technology comes from deliberate actions within the system, as a method for overall growth (Lucas, 1988; Romer, 1986, 1990).

I consider a wider definition of innovation to be relevant in this thesis as well. Entrepreneurs deal not only with monopoly situations (innovation as monopoly rents akin to Schumpeter), but also with arbitrage and incremental efficiency increases (Kirzner, 1985, 1997; Leibenstein, 1968, 1979). The relevant dimension is that entrepreneurs are occupied with the discovery of profitable niches or opportunities which abound in the imperfect world. Imperfections in demand or supply in certain regions create profitable opportunities. It is a better justification for the existence of travelling merchants than the Schumpeterian entrepreneur. These entrepreneurs also innovate, yet they are more concerned with reducing inefficiencies in their business rather than creatively destroying markets.

The scope of the CIS encompasses both views, justifying the inclusion of both views of entrepreneurs. In this thesis, I consider the actions of the firm to be the actions of the entrepreneur.

The innovation strategy is a summary of firm choices while innovating. These choices are the outputs of managerial decisions. This definition is more strict than is often found in firms' internal documents. "*Strategy is a set of goal-directed actions a firm takes to gain and sustain superior performance relative to competitors*" (Rothaermel, 2017, p. 6). This definition concludes nicely, drawing on many other known authors of strategic management. The relevant coinciding parts of both definitions are that strategy consists of actions and choices to achieve competitive advantages. Innovations are a means to superior performance. However, they may not be the only tool. This restriction is important in this thesis. I investigate the set of actions for firms while they are undertaking innovative activities. Firm choices and actions for other activities are, unfortunately, out of scope.

The data about innovative activities used in this thesis comes from the Estonian Community Innovation Survey (CIS) gathered by Statistics Estonia. The CIS is a homogenised biannual survey in the EU, coordinated by Eurostat and part of the EU science and technology statistics. The CIS is a representative survey of firms with over 10 employees. Firm innovation strategies are estimated based on CIS data about Estonian firms between 2002 and 2012. A detailed description of the CIS, its possibilities and weaknesses is in Chapter 4.1.

The CIS data about innovative activities is merged with exogenous data about public sector policy instruments. Data is gathered directly from the largest paying agencies and other relevant registers. Altogether, it consists of all known relevant policy instruments available to firms in Estonia between 2002 and 2012. I believe this to be the most comprehensive database of policy instruments in Estonia. Further description about policy instrument analysis is in Chapters 3 and 4.2.

The main methods for estimation in the logical consequential order, the same as for the objectives, are as follows. I use exploratory factor analysis to reduce the dimensions of firm choice and extract groups with k-means clustering. These groups are the basis of patterns of innovation, i.e. strategies with enough similarity. I describe the dynamics of these patterns with visual techniques usually applied in discrete state analysis and estimate state transition matrices for probabilities of shifting from one innovation strategy to another. I proceed with generalised mixed models with binary outcomes to estimate the relationships between patterns of innovation and innovation outputs. I proceed to estimate the probabilities to shift strategies for firms with treatment with multinomial logit models. Finally, I will conclude estimations with multi-state Markov models to describe possible shifts between different innovation strategies when firms have received business support.

Multi-state Markov models are proficient for estimating the dynamics in settings where there is a high number of possible trajectories. In the models presented in Chapter 9, multi-state markov models are used to analyse more than seven thousand different combinations of firm innovation strategy dynamics.

Some notes on terminology are below. Firm innovation strategy refers to the choices of a single firm while conducting innovative activities. Patterns of innovation[3] are a combination of such strategies. Therefore, patterns of innovation represent the dominant choices firms make. Patterns of innovation are combined in a manner to create the largest between-group heterogeneity while preserving the largest within-group homogeneity. In other words, firms in a group should be as similar as possible and as different from other groups as possible.

To the extent of my knowledge, this thesis presents the most broad estimation between innovation strategies, innovation outputs and public sector support that is currently available to the public.

[3] Also referred to as innovation modes (Frenz and Lambert, 2012; Hollenstein, 2003), patterns of innovative activities (Malerba and Orsenigo, 1997), technological trajectories (Castellacci, 2008)

I contribute to our understanding of innovation policies in three ways. First, I investigate the effects of state intervention with policy instruments. Both innovation outputs and innovation strategies are important measures of outcomes of innovation policies. The former relates to firms being more innovative, i.e. the aim of policies are usually to accelerate the creation of innovations, and the latter, to the types of innovative behaviour that these interventions are generating or accelerating. A simple example would be the interventions generating behaviour which supports high-tech product innovations or low-tech process innovations.

Second, I contribute by investigating the dynamics of firm innovation strategies with panel data. There are solid theories for doing this, which can be found in different streams of literature, but there are not many empirical investigations. Beyond case studies, estimates of innovation strategies have been cross-sectional, e.g. De Jong and Marsili (2006), Hollenstein (2003), and Leiponen and Drejer (2007). A single study with dynamics has been published in Switzerland as a discussion paper (Hollenstein, 2018). Hollensteins (2018) is the most comparable to the estimations in this thesis. Large scale studies in this manner with representative population samples have not been done before, to the extent of my knowledge.

Third, I contribute to the relevant knowledge by introducing a new taxonomy of public sector support which is given directly to firms. This taxonomy is an example of all policy instruments available to firms during a ten-year period. Drawn from empirical observations, it gives a contrasting picture to theoretical taxonomies usually found in the innovation policy literature. Based on this grouping, I estimate the relationship between innovation activities, outputs and public sector support.

The structure of the thesis is the following. First, I introduce the innovation process within the firm and the possible choices for firm innovation strategies in Chapter 2. Second, I introduce the possible public interventions with policy instruments to the firm and analyse the rationales for intervention. I conclude with a taxonomy of public sector policy instruments which are directly aimed at the firm and point to how it influences the firm innovation process in Chapter 3. Third, I introduce the sources of data and describe what is in the data and what is not, in Chapter 4. Fourth, I give an overview of the Estonian business environment and relevant descriptive statistics about innovative activities in Chapter 5. Fifth, I describe the methods used for estimations in every estimation chapter: 6.2, 7.2, 8.2, 9.1. Sixth, I estimate the dynamics of innovation strategies in Chapter 6. Seventh, I estimate the relationship between firm innovation outputs and public sector support in Chapter 7. Eighth, I estimate the relationship between dynamics of firm innovation strategies and public sector support in Chapters 8 and 9. Finally, I conclude the thesis in the discussion and conclusions chapter.

2. FIRM INNOVATION STRATEGIES

2.1. Technological regimes

Firms' choices in the innovation system are constricted by the nature of their production or services and, therefore, by the competitive environment in which they stand. This applies for the technological nature of production, but also for other means, in which the firm can search for innovation – organisational structure, design, marketing, process, etc. This section describes in detail the possible search mode for innovation and its relation to the sectoral level of the firm and its competitive environment.

The role of economic and technological restrictions imposed by the competitive environment for the innovation process is described by technological regimes (Nelson and Winter, 1982; Winter, 1984) and technological paradigms (Dosi, 1982, 1988b). The latter emphasises differences between sectors, based on historical evidence of technological change. Within these paradigms, technological trajectories describe the search process for a single firm.

Firms seek innovation for a competitive advantage, a technology or process to give them an edge on the market. The technological regime in which it operates dictates four elements of this innovation process. These elements are the sources of technological opportunity, the appropriability conditions for rents, the cumulativeness of innovations and the complexity of the knowledge base. I will discuss all four elements in turn.

Technological and scientific opportunities within a technological regime depend on the current technological level and knowledge created within the technological regime, in other technological regimes and conditions imposed within the innovation system as a whole. Scientific opportunities may open new possibilities within the current paradigm or create new competing paradigms that will come to dominate old ones. An example of a technological regime is the push for lighter and more durable materials and effective design to reduce seat cost per mile on air crafts (Nelson and Winter, 1977). The opportunities are driven by the market, i.e. competitive advantage comes from lower cost, where long flights and high volumes are demanded. The technological regime defines the opportunities available to the innovating firm, therefore reducing possible search costs. In the case of early 20th century aviation technology, opportunities before the advent of small electric components and lighter materials were limited. At one point, advances in jet engines were enough to dominate the old technological regime.

Technological opportunities can also be included in other search modes, such as the design of products or the work process itself. These may yield more incremental innovations. Depending on the technological regime of the sector, there is variance between possible scientific or technological opportunities. To compare, the process of innovation in pharmaceuticals entails R&D in the form of developing new chemicals, rigorous testing in and out of the laboratory and finally releasing a product. The process of innovation in wood harvesting technology involves R&D in the form of utilising more materials, designing efficient machinery and workflow and reducing waste. The nature of opportunities in these two examples are in different activities, yet, in both cases, they describe possible avenues of search. The possible scope of the search for innovations is limited, therefore reducing costs in the innovation process.

The appropriability conditions in different technological regimes influence the possible methods for rents. R&D activities may have qualities of a public-good nature and positive spillover effects, which in turn might discourage firms to undertake these activities (Arrow, 1962; Nelson, 1959). Firms expect to be compensated for these activities through protection of their innovations from imitation or by external funding (Teece, 1986). This issue is not limited to R&D activities. Design, work process and products can also be imitated by competitors. In some technological regimes, e.g. pharmaceuticals, formal appropriability methods are prevalent, such as patenting. In others, e.g. food production, secrecy of components or work process, package design and branding can be used. The appropriability conditions can be changed with public policy to promote innovation in a specific technological regime (Levin et al., 1987). However, in many technological regimes, lead time from imitators, secrecy, service and sales efforts matter more than formal intellectual property rights institutions. Levin et al. (1987) suggest a case-by-case approach to public policy in managing appropriability conditions, in which technological regimes are analysed on the sectoral level to ensure an effective approach for fostering innovation.

The cumulativeness of innovations in the technological regime characterises whether innovations are of an incremental or radical nature. This is also associated with the Schumpeter Mark I and Mark II patterns of innovation (see next subsection). The incremental nature of innovations builds upon previous technological advances, where incumbents or previous innovators have an advantage in the technological regime. In sectors with very high cumulativeness of the technological regime, entry barriers are also higher. Breschi et al. (2000) describe four different levels of cumulativeness which are associated with the technological regime. They can take place at the technological, organisational (firm level), market (the 'success breeds success mechanism') and industry (through spillovers) level.

The complexity of the knowledge base describes on what type of knowledge the innovation process draws. The knowledge base can be described in at least two dimensions, firstly, the level of tacitness of skills and knowledge. Karl Polanyi (2009) wrote that "we know more that we can tell." There are elements of any technology or innovation process which are hard to imitate because they can not be codified. If workers are unable to describe their skills and are only able to teach them, e.g. the master-apprentice system, it also limits the easiness in which potential innovators can "dip in the public knowledge pool." Tacit skills can be acquired on the market as well, for example, by employing workers from competitors. However, the costs associated with tacit knowledge can be high, since its transfer between people is uncertain (Kogut and Zander, 1992). Codified knowledge within a firm can be its working manuals or rules, customer banks and so forth. Outside the firm, codified knowledge is available about public basic research or market preferences. It depends on the firms' own capabilities to apply this knowledge.

A second dimension of the knowledge base describes the specificity of knowledge. Generic knowledge can be applied in a very broad manner, permeating different technological regimes. Specific knowledge is targeted in a narrow set of problems. Another distinction of the same nature is that basic science develops broad generic understanding, which can also be used in applied science. However, applied science develops knowledge which stems from practical issues (Breschi, Malerba, and Orsenigo, 2000). The knowledge base of a technological regime can also vary on its independence from other technological regimes, depending on how much of its knowledge can be extracted and separated from a larger system.

Table 2.1: Major dimensions of technological regimes

Opportunity	Appropriability	Cumulativeness	Knowledge base
Level	Level	Technology	Generic/specified
Pervasiveness	Means	Firm	Tacit/codified
Variety		Sector	Simple/complex
Sources		Area	Independent/system

Source: Breschi and Malerba (1997)

Table 2.1 highlights the major dimensions of technological regimes that have been described in this section.

The concept of technological paradigms captures the essence of technological regimes in a more sector and technology specific manner. Dosi (1982; 1988) analyses technological paradigms in different sectors and further develops upon technological trajectories. A natural trajectory, i.e. a process, is one for which firms innovate within their own technological paradigms. Dosi (1988) highlights the microeconomic setting for technological paradigms and trajectories, emphasizing the diversity between sectors and technology based on examples from many different sectors.

Technological trajectories are mostly within sectors. There are also major technological revolutions in human history, when some technologies disrupt multiple industries at the same time. Currently, we are beyond the fifth technological revolution, which was indicated by the coming of the microprocessor (Perez, 2009) — the age of information and telecommunications. Previous ages are characterised by the coming of the industrial revolution, steam engines, electricity and so forth. Technological changes have been pervasive in the whole of society, creating new working conditions, working and leisure cultures, cultural institutions and actors in society (Mokyr, 2002).

These ultra-long waves of techno-economic paradigms shape all industries, creating new technological regimes at the same time (Freeman and Perez, 1988). In essence, technological regimes and trajectories are found within larger techno-economic paradigms. When a new techno-economic paradigm has been initiated and the catalyst innovations are diffusing rapidly in many sectors, we would expect turbulent choices as well for innovation strategies. In the context of this thesis, if firms are receiving an influx of new technologies and knowledge which they have been derived of from before, say due to development level or political reasons, a microcosm in the sense of techno-economic paradigms is possible.

The dimensions of technological regimes can take a variety of different combinations. One approximation is using the logic of technological regimes to analyse sectoral patterns of innovation. Three major taxonomies or typologies are discussed here, emphasizing different aspects of possible combinations of the underlying dimensions in technological regimes – Schumpeterian patterns of innovation, the Pavitt's taxonomy, and the high-tech low-tech divide.

2.1.1. Schumpeterian patterns of innovation

Based on Joseph Schumpeter's writings, *The Theory of Economic Development* (1934) and *Capitalism, Socialism and Democracy* (1942), two distinct concepts for patterns of innovation have been noted (Breschi and Malerba, 1997; Breschi, Malerba, and Orsenigo, 2000; Malerba and Orsenigo, 1996, 1997; Nelson and Winter, 1982; Winter, 1984).

Schumpeter Mark I is a pattern of innovation described by creative destruction, the significant role of entrepreneurs, smaller firms, and entry and exit. Also referred to as a "widening" pattern of innovation (Breschi, Malerba, and Orsenigo, 2000) or an "entrepreneurial" regime (Winter, 1984), where main innovators have not innovated before. The technological regime where Mark I patterns of innovation exist is characterised by high opportunities, relatively low technological barriers for entry and no fixed hierarchy for innovators, i.e. low cumulativeness and low appropriability. These signify a disequilibrium state in the market, where firms have ease of entry and seek disruptive change.

Schumpeter Mark II is a pattern of innovation described by high cumulativeness, large R&D investments and laboratories, large market power of incumbents and stability of leading innovators. Also referred to as a "deepening" pattern of innovation (Breschi, Malerba, and Orsenigo, 2000) or a "routinized" regime (Winter, 1984). Mark II is a pattern of creative accumulation, i.e. the same agents introduce innovations repeatedly. Mark II characteristics of technological regimes are high opportunity, high cumulativeness and high appropriability. This means that a smaller group of incumbents are innovating within the sector, due to restrictions of entry or resources needed for innovation.

2.1.2. Pavitt's taxonomy

Pavitt's taxonomy (Pavitt, 1984) is a well-known sectoral taxonomy of patterns of innovation. Pavitt (1984, p. 343) aimed to describe similarities and differences amongst the sources, nature and impact of innovations in sectors. Pavitt used inductive reasoning mainly to combine the technological trajectories of different firms within sectors into a taxonomy. Three main dimensions of technological trajectories were assessed (Pavitt, 1984, p. 343):

- The sectoral sources of technology used in a sector: in particular, the degree to which it is generated within the sector, or comes from outside through the purchase of production equipment and materials.
- The institutional sources and nature of the technology produced in a sector: in particular, the relative importance of intramural and extramural knowledge sources, and of product and process innovations.
- The characteristics of innovating firms: in particular, their size and principal activity.

A distinctive characteristic is the focus on the interrelations between knowledge and technology providers. It combines the elements of technological regimes with actors in the innovation system. Compared with Schumpeterian patterns of innovation, this approach is focused more on firms' choices in the innovation system, the technological trajectories within sectors, and then the results are aggregated (Castellacci, 2008). These relations as a basis for taxonomic deduction allow technological regimes and trajectories to be compared on a sectoral and firm-level basis (Archibugi, 2001).

Pavitt's taxonomy concluded four major categories:

- Supplier dominated – Sources of technology are suppliers, big users and extension services. The main method is process innovations. Typical users are price-sensitive, and technological trajectory is cost-cutting. Technological diversity is low and vertical. The relative size of innovating firms is small, and the main means of appropriation are non-technical, such as trademarks, marketing, advertising and aesthetics. Example sectors are agriculture, construction and traditional manufacturing.

- Scale intensive (production intensive) – Sources of technology are production-engineering department suppliers and in-house R&D. The main method is process innovations. Typical users are price-sensitive, and the technological trajectory is cost-cutting in product design. Firms tend to be large with high vertical technological diversity. The main means of appropriation are process secrecy, know-how, technical lags, patenting and dynamic learning economies. Example sectors are steel, glass (materials) and cars.

- Specialised suppliers (production intensive) – Sources of technology are in-house R&D and users demand. The main source for opportunities is based on design and development to match user need. The main method is product innovation. Firms are typically small and concentrated in technological diversity. Customers are performance sensitive, and main means of appropriation is design know-how, knowledge of users and patenting. Example sectors are machinery and instruments.

- Science based – Sources of technology are in-house R&D, knowledge based on public science, engineering departments and suppliers. It is characterised by mixed methods of innovation and mixed technological trajectories. Firms are typically large with low intensity and vertical technological diversity, or high intensity and concentrated technological diversity. The main methods of appropriation are R&D know-how, patents, process secrecy and dynamic learning economies. Example sectors are electronics and chemicals.

These stylised commonalities between sectors show how firms are not always free to search for innovations in any knowledge base or range of possibilities, but rather technological change is cumulative. The nature of technological change is dependent on firms' past behaviour.

A later addition included one more group to this taxonomy, which has been forethought (Pavitt et al., 1989):

- Information intensive – Sources of technology are software departments and specialised suppliers. Typical core products are financial services, retailing or software products. The main trajectory for technology is efficient and complex information processing with related products.

This basic trajectory has been relevant in further studies and recognised in empirical works as well (e.g. Castellacci, 2008; Hollenstein, 2003; Miozzo and Soete, 2001).

2.1.3. High-tech versus low-tech

This is likely the most popular method for classifying industries. The main link of this taxonomy with innovation patterns is the linear model of innovation, i.e. science push model. It implies that basic science leads to applied science and the product development phase before it is sold on the market (Bush, 1945; Godin, 2006). The scientification of the innovation process creates simplicity. To create innovations, according to this model, more basic science and R&D is needed, and innovations will follow. This simplification is also appealing to policy-makers (Caracostas, 2007).

This taxonomy is available in several major databases, calculated on a sectoral level (e.g. OECD, Eurostat). Though some details can vary, the major contributor to classification is the percentage of R&D within firms or sectors. An example is the OECD classification, where R&D above 5 percent is considered high-tech (Hatzichronoglou, 1997). This classification has elements which are critiqued, mainly, because economic growth, cohesion and competitiveness rests above all on low- and medium-tech enterprises, while most attention goes toward high-tech industries (Hirsch-kreinsen et al., 2003). Nevertheless, in general, it is not wrong to emphasize the role of high-tech industries (Heidenreich, 2009). However, the high-tech-low-tech divide lacks analytical capabilities when trying to encompass technological regimes (Von tunzelmann et al., 2008).

2.2. Technological regimes of service sectors

Literature about the technological regimes of service sectors has been mainly developing along three approaches (Coombs and Miles, 2000; Gallouj and Savona, 2009).

The assimilation or technologist approach rests on the assumption that innovation in services is similar to manufacturing and therefore can be studied in the same context. Tools and frameworks already developed in the manufacturing context are either directly applied or widened to encompass service peculiarities (e.g. Evangelista, 2000; Hollenstein, 2003; Miozzo and Soete, 2001). An important assumption or justification is that innovation in services has become increasingly technology and capital intensive (Gallouj and Savona, 2009). A very clear example is the widespread use of ICT in service industry innovations.

The assimilation approach is a widespread way of analysing innovations in service industries (Carlborg et al., 2014; Witell et al., 2016). Especially when considering the original Pavitt's taxonomy, the assimilation approach can be used to combine manufacturing and services within the same framework. This is most aligned with the Schumpeterian view that innovations are outcomes new to the world and create exchange value (Witell et al., 2016). The downside is that it emphasises the technological nature of innovations, not encompassing non-technological innovations as much.

The demarcation approach holds that innovations in services are highly unique and therefore require novel theories and instruments. Studies in the demarcation approach expect different surveys for services and manufacturing firms, or at least dual-approach surveys where different questions are asked for either. Unless services overall or a single sector are in question, the demarcation approach is not very well suited for analysing services and manufacturing firms combined.

The synthesis or integrative approach appeals that service innovation perspective is suited for analysing both manufacturing and service industries. The key is to understand the converging nature of manufactured goods and services and create a common framework. However, this also assumes re-defining products and services (Gallouj and Savona, 2009).

In this thesis, the assimilation approach is the most appropriate. First, innovation strategies are considered at the same time for both manufacturing and service firms. Second, it is the most appropriate when considering the Community Innovation Survey (CIS) as a starting point for empirical work (Gallouj and Savona, 2009). Third, the addition of other innovation outcomes besides product and process in the CIS has already converged some of the distinctions between manufacturing and services. Service sectors were seen as laggards in terms of innovation and innovative activities when considered in theories about technological regimes (Pavitt, 1984). All services were categorised at first as supplier-dominated, meaning they are passive adopters of technology created elsewhere. Later addition to Pavitt's taxonomy included financial and retailing services in the information-intensive technological trajectory (Pavitt et al., 1989).

Technological regimes in service innovations have included networking effects, either physical or informational, as one major contributor (Miozzo and Soete, 2001). Example industries are transportation and financial services. These industries are using their infrastructure network to define what types of innovations are necessary and include very large firms with enough capacities to develop their own innovations. Recently, this has been adopted together with scale-intensive firms to create a scale- and information intensive trajectory (Bogliacino and Pianta, 2016). The main descriptions include large firms, extensive adoption of ICT and cost competitiveness.

Another important distinction in technological regimes of service innovations is knowledge intensive business services (KIBS) (Miles, 2006). They represent firms which are highly reliant on expert knowledge, whereby a large proportion of the labour is highly educated. These firms mostly provide services to other firms, so their customers are organisations. Examples include architects, software developers, lawyers and so on. A good nickname for some of them is “problem solvers for advanced manufacturing firms” (Castellacci, 2008, p. 981). A comparable trajectory in the classic Pavitt’s taxonomy would be specialised suppliers.

2.3. Evolution of innovative activities

2.3.1. Product life cycle and reversed product life cycle

The dynamics of innovation strategies are linked to the product life cycle theory. Firms develop new products and shift strategies to optimise processes for production (Utterback and Abernathy, 1975). Innovation strategy stages can be seen on a product level (Abernathy and Utterback, 1978). This model links together innovation or competitive strategies, the stage of production development process and innovative activities (Gallouj and Savona, 2009). Before dominant designs appear, many competitors build on radical innovations and test new concepts on the market. After standardisation occurs, strategies involve production processes and cost efficiencies, which yield competitive advantages.

The product life cycle theory predicts that at first, firms concentrate on product innovations. These radical innovations aim to maximise perceived quality (Gallouj and Savona, 2009). After that, incremental innovations take over. Markets get used to the innovations as the product reaches maturity and market starts to get saturated. Then the focus shifts to process innovations. Strategies involve more production methods and cost reductions in the final stage.

This model shows why both product and process improvements as innovative outputs are important for productivity growth and competitive advantage. Understandably, this simple model cannot fit every circumstance. Pavitt (1984, p. 365) also observed that it is possible that whole industries may shift from one technological trajectory to another when their process technology has matured.

In service industries, this model can be seen working in opposing direction. The reverse product life cycle predicts that, in the first stage, new technology is applied to increase the efficiency of delivery of services. In the second stage, technology is applied to increase the quality of services, and, in the third stage, technology is applied to generate new services (Barras, 1986, 1990). The role of product and process innovations is reversed in this model when compared to the product life cycle model.

This shift in trajectories over time is mainly related to IT-based innovations. Judging from the era, when these ideas have been formulated, most economic areas were on the verge of applying IT to any conceivable process. However, not anecdotally, Barras notes that these shifts were visible between the 1970s and 1990s in the financial sector and local governments (Barras, 1986, 1990).

Critically, the reverse product life cycle approach can be considered to be based on too much emphasis on technological innovations (Gallouj, 1998). Innovation activities can result in innovations which are not just new products or processes. Therefore, the reverse product life cycle model is probably only one type of dynamic which can be seen in service innovations and strategies. Some evidence is provided in a paper about the Thai banking sector (Uchupalanan, 2000). A range of possible dynamics were seen in adopting IT and innovating services in just one business sector. Interrelations between competitors, regulators and innovation phases were seen to be too important for dynamics of innovation activities, such that the reverse product life cycle model is just too simplistic. However, the importance of the reverse product life cycle framework in highlighting possible dynamics in service innovation dynamics has been important (Miles, 2006).

Based on these theories about the dynamics of activities undertaken in different phases of products, we can expect to see firms starting in a more radical innovation trajectory and ending up in a more process innovation trajectory. The early phase includes more R&D and later phases more outsourcing and cost competitiveness. Also, we can expect to see differentiation between manufacturing and service industries, where services may follow an opposing path. However, theories about dynamics are sometimes discussed in long timespans nearing Kondratiev waves, which are not measured with data used in this thesis. Therefore, we expect to see relatively mild shifts for firms between different innovation strategies over time.

A question also rises about the unit of analysis. In the product life cycle and reversed product life cycle, theories dynamics of innovative activities are proposed on the product level. We cannot see innovative activities on the product level in most surveys, but rather on the firm level. It is safe to assume that most firms produce more than one product.

However, when the unit of analysis is the firm, there may be conflicting strategies on a product level, since most companies produce more than one product. Although most sales and exports come from a few core products (e.g. Arkolakis and Muendler, 2010), most firms also shift their product lines as often as every five years (Bernard, Redding, et al., 2010). If we know this, but cannot observe more than one product per firm, we also cannot observe if there are different strategies or innovative activities involved with regard to different products. If these strategies are conflicted within the company for different products, then our current surveys are unable to disentangle these strategies properly.

2.3.2. Industry life cycle

The industry life cycle view has similarities with Schumpeter Mark I and Mark II patterns of innovation. In Mark I industries, small firms have an important role. There are low barriers to entry and small incumbent advantages. In Mark II industries, cumulativeness and high appropriability are more important. Incumbents are mostly larger firms with R&D departments and high capitalisation.

The industry life cycle view presents these ideas simply: young industries have higher innovation rates than declining industries, and product innovations are replaced with process innovations when industries mature (Klepper, 1997). Therefore, it is expected that firms can change from a Schumpeter Mark I to a Mark II pattern of innovation over the course of its life (Malerba and Orsenigo, 1995).

We expect to see industries with younger and smaller firms to have higher rates of product innovations and a higher rate of new to the world innovations. Alternatively, we expect to see industries with a more equally distributed market share to have more radical innovations and more frequent change in leading innovators. Empirical evidence about levels of R&D and change in innovative behaviour over industry life cycles is still mixed (Bos et al., 2013; Mcgahan and Silverman, 2001; Tavassoli, 2015).

2.4. Strategic management view

2.4.1. Resource based view

Sources of competitive advantage are the focus of scholars in strategic management as well. The clear emphasis is on the firm specific effects. Every firm should adapt to its external factors, but ultimately it relies on its own competencies. If these competencies are unique to the firm, truly embedded and allow product differentiation on the market, they are firms' core competencies (Prahalad and Hamel, 1990). These can be the source of competitive advantage. Core competencies must permit potential access to new markets, be seen by the customers as a principal source of value, and be difficult to imitate by competitors.

Core competencies rely on resources and capabilities within the firm. Resources are assets such as cash, machinery or intellectual property. They can be either tangible or intangible. Capabilities are skills, organisational practices and culture, which are intangible. Capabilities are visible in the company's structure, management practices, culture and routines. Interplay between resources and capabilities become activities, which can be thought of as business practices[1]. Turning inputs into goods and services and selling them are the ultimate goals of activities.

[1] Similar ideas have been described as routines in the technological regimes literature, e.g. see Nelson and Winter (1982).

The resource based view of the firm sees firm resources as the driver to competitive advantage. Deployment of resources with firm specific capabilities are the source of core competencies. The resource based view rests on two important assumptions (Barney, 1991). First, firms within an industry can be heterogeneous in their control of strategic resources. This assumption declares that bundles of resources and capabilities are unique, even within the industry, and both tangible and intangible resources and the capabilities to use them are allocated unequally. Therefore, unique bundles can be found in every firm, which allows them to compete. This is a clear violation of the perfect competition model. Second, these resources are not perfectly mobile, thereby creating long lasting heterogeneity. According to this model, the deliberate creation of this control over possible resources is the source of long term competitive advantage. The stickiness of resources creates competitive advantages, and resources and capabilities which are hard to imitate can extract long-term rent.

In this model, resources are all tangible and intangible assets which a firm uses to choose and implement its strategies (Barney, 2001, p. 54). Tangible assets are visible with physical attributes such as labour, land, buildings, machinery, supplies, etc. Intangible resources are invisible, without physical attributes, such as culture, knowledge, brand equity, reputation, property rights, etc. Scholars also divide important resources into somewhat different categories (Wójcik, 2015), for example, physical capital, human capital and organisation capital (Barney, 1991) as well as technological, reputational and financial resources (Grant, 1991).

Competitive advantages are created when these resources should be valuable, rare, imperfectly imitable and non-substitutable - known as the VRIN criteria (Barney, 1991). If a firm develops resources that meet all VRIN criteria, they can be thought of as entry barriers for new firms as well (Wernerfelt, 1984).

Capabilities can be described as the mode in which resources are used — the practices, activities, capacities and so forth. Several influential definitions are found in the literature[2]. Capabilities are a set of high-level routines, that convey decision options for the management in creating outputs from inputs (Winter, 2000). The important nature of these routines are that the management is somehow aware of them. If the routines are invisible within the firm, then there may not be any way to influence or take advantage of them. Capabilities, by definition, are tools.

Another possible notion is that capabilities are skills that are necessary in employing possible resources and consciously using them strategically (Rothaermel, 2017). Skills and routines both convey the message that there is managerial control and ability involved. Lastly, capabilities are described as processes within the firm that use resources to match and create market change (Eisenhardt and Martin, 2000). This definition adds dynamic nature to the idea of capabilities, that they

[2] An overview can be found in Wójcik, 2015, p. 91.

create or provoke change within the firm while using resources. It is an important idea for this thesis to describe the advancement of dynamic capabilities theory in creating competitive advantage for the firm.

Commonly, capabilities are skills, routines or processes to use resources in a desired result for creating competitive advantages through differentiation strategy or resource efficiency (Wójcik, 2015). This paper adapts the idea a bit more simply, conceiving capabilities as conscious organisational processes which enable utilisation of resources to a desired effect.

2.4.2. Dynamic capabilities

The resource based view can be criticised in viewing the competitive environment as static. Competitors develop new technologies, new markets, innovative products and processes that may be well above a firm's core competences in regards to resource efficiency or organisational capabilities. Core rigidities are processes that hinder a firm's ability to develop and deploy resources (Leonard-Barton, 1992). In parallel, core competencies can turn into core rigidities when firms are not agile enough in changing with the environment.

Therefore, firms' resources and capabilities to deploy them should be in constant change, or rather be upgraded, modified and leveraged to create competitive advantages over time (Eisenhardt and Martin, 2000; Teece et al., 1997). This is known as the dynamic capabilities approach to competitive advantages. The idea is to create sustained competitive advantages over short-term or short-lived advantages (Rothaermel, 2017).

Dynamic capabilities bring forth new theoretical constructs. If firms have processes evolving over time, then there are also path-dependent histories of firms at play (Teece et al., 1997). Path-dependency has been acknowledged as a possible mechanism affecting firm choice in markets (Arthur, 1989). When capabilities are described as processes or skills, then this notion becomes not only technological but rather practical in management. If there are possible strategic choices in utilising some resources that yield maximal return, then this practice should be used. However, it should be used by competitors as well. Dynamic capabilities predict change in firm behaviour in making these managerial choices, the process of deploying resources to maximise return, therefore predicting the possible emergence of best practices (Eisenhardt and Martin, 2000). In essence, there are processes which are universal for firms, and many practices emerge which are considered to be the best.

For example, recent years have seen an advocacy for so-called open offices. They are supposed to provoke interaction, cooperation and creativity and increase performance (Waber et al., 2014). The concept is naturally simple, recognising that as people are given more space and possibilities for networking, as social beings, they will do just that. Firms may therefore take advantage of the inherent nature of humans to network. The layout of the office, a tangible resource, is a simple matter for the managers to organise. Therefore, if it truly boosts performance, dynamic capabilities would expect open offices to turn into a best practice, universal to all firms. In the end, we would all work in one. Fortunately, there is some evidence that the expected gains in collaboration in open offices may not always be there (Bernstein and Turban, 2018).

This example highlights possible shifts in firms' processes. Changing the tangible resources has intangible effects on collaboration and office culture. They change the possible routines within the firm, both visible and invisible. The point here is not to advocate for or reject open offices, but rather to illustrate how this change is expected in the dynamic capabilities' perspective. Managers are expected to take advantage of every piece of new information on possible best practices and utilise them to the advantage of the firm. If it would really turn out that open offices are a godsend to mankind's performance, cubicles would be slowly dying out as an evolutionary process of design.

Common features among firms can create similar value and at the same time exhibit different processes. An example of the knowledge creation process shows that a common feature in firms is having external linkages with outside knowledge sources (Eisenhardt and Martin, 2000). At the same time, there are different possible forms for these external linkages, such as informal relationships, relations driven by promoting active relationships with the wider community within the firm, and formal alliances.

The dynamic capabilities perspective also highlights the difference between resource stocks and resource flows (Dierickx and Cool, 1989). Resource stocks are static, the amount on balance from which a firm's competitive position can be estimated. However, strategy involves choosing optimal resource flows. Resource flows create long-term advantages, they are investments to maintain resources. This applies to intangible resources as well. For example, Apple's ability to market and charge a premium for its products cannot be created and replicated overnight. The reputation, prestige and level of expected consumer comfort that Apple is known for are intangible resources which receive constant investment.

The dynamic capabilities approach highlights two features important in this paper. First, firms rely on the resources that are available within their environment. These resources are both tangible and intangible. Also, capabilities to utilise these resources matter. The combination of both are varied between firms even in the same industries, yielding non-perfect competition we see in most markets. Second, there are dynamic processes involved. The adage *competition never sleeps* captures this in full. For a firm to stay competitive and extract rent on the market, constant change in developing and utilising resources is needed.

Based on these assumptions, we would expect to see high variation between firms in the same industries. Industry specific effects on creating competitive advantages are less important than firm specific effects. Also, these assumptions predict a constant change within the firm to utilise its possible resources, a constant upgrade of processes to remain competitive. Without adapting and developing, firms lose competitiveness and are forced out of the market.

2.5. Open Innovation

Both the strategic management view and technological regimes concepts acknowledge the role of external partnerships. The idea that firms can actually shed costs and create strategic competitive advantages by sharing their R&D and innovation efforts by opening up their processes really took off after the influential work by Chesbrough (2003). "*Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively*" (Chesbrough, Vanhaverbeke, et al., 2006, p. 1). Many firms use open innovation strategies to keep up with competitors and meet market demand, which makes this concept useful beyond R&D (van de Vrande et al., 2009).

Firms can leverage both the inbound and outbound open innovation to their advantage (Chesbrough and Crowther, 2006). Inbound open innovation includes the acquisition of external technologies and knowledge to the firm through R&D contracts, university partnerships, in-licensing, M&A deals and so forth. The general idea is that firms need not rely only on in-house R&D capabilities to leverage new knowledge and technologies in their innovation process. Outbound open innovation includes licensing own technology to others via intellectual property licencing, spin-offs, joint-ventures or other mechanisms. Firms do not need to leverage everything they created themselves, but can support their own revenue stream by letting other partners open up new markets with the technology they have sold or licensed off. Outbound open innovation lets firms concentrate on their own core activities and, at the same time, benefit from their R&D efforts by letting others exploit them. Inbound open innovation can be described as either sourcing or acquiring, and outbound open innovation as selling or revealing (Dahlander and Gann, 2010).

The open innovation paradigm emphasises firms' use of internal and external ideas to create a competitive advantage and advance their pursuit of innovations. The role of searching for innovations implicitly also describes how firms' innovative activities are shaped by external ideas (Dosi, 1988a; Nelson and Winter, 1982).

Similarly, the concept of absorptive capacity shows that firms need be willing to accept and use information coming from external sources (Cohen and Levinthal, 1990).

Still, open innovation has been influencial in research. Measuring openness by just the amount of partnerships per firm has shown that being more open has a positive relationship with firm performance and innovativeness (Laursen and Salter, 2006; Love et al., 2014). Small firms can also benefit, even though there are substantial costs in finding partnerships and firms are not very keen on adopting open innovation practices (Vahter et al., 2013; Wynarczyk et al., 2013).

Hewitt-Dundas and Roper (2018) point to three market failures which might hinder strategies which are based on more cooperative relationships. These is (i) a lack of awareness of the benefits of cooperating; (ii) limited information on functional capabilities of potential partners; and (iii) limited information on trustworthiness (Hewitt-Dundas and Roper, 2018). Policies designed to remove or reduce these barriers can influence the strategy of the firm to be more cooperative and take on new partnerships. Policies to support open innovation can align well with what is already influencing firms, although it broadens the scope of innovation policies (De Jong, Vanhaverbeke, et al., 2008).

2.6. Innovation process within the firm

Previous sections described the search mode for innovations, the possible motivation and constraints for creating innovation strategies. Finally, I will introduce a model of the innovation process that will elaborate the processes described before.

The model presented here is somewhere along the fifth, and currently last, generation of innovation process models (Rothwell, 1994). There have been several, if not dozens, of innovation process models presented in the previous four generations (Godin, 2015). Since the fifth generation model is an expansion of previous models, I will only briefly mention the biggest improvements.

The first generation is called a technology push model or linear innovation model. It forms a direct sequential relationship between basic science, design and development, manufacturing, marketing and sales.[3] This is a straightforward process where all innovations can be traced back to basic science. The simplicity is one explanation for the heavy focus on R&D in innovation policies (Caracostas, 2007).

The criticism of the lack of demand factors in the linear model led to the second generation of innovation process models — the demand push model (Godin and Lane, 2013). The model contrasted the technology push model by iterating the market need as the first step of the sequential relationship towards innovations.

[3] This model also has no clear authors. A review of its history can be found in Godin (2006)

Innovations come from market needs, which are then developed (basic science and R&D), manufactured and commercialised.

The third model of innovation — an integrated model — combined both supply and demand factors (Marinova and Phillimore, 2003). The innovation process was still considered to be a linear process but with feedback loops (Rothwell, 1994). Processes can contain loops and feedback mechanisms to assess whether they should continue, be revised, follow through to next steps or be abandoned altogether (Kline and Rosenberg, 1986).

The fourth generation of models combined this knowledge and started emphasising systems (Marinova and Phillimore, 2003). One example is the national innovation system (Edquist, 1997; Lundvall, 2010), where the role of actors outside the firm is highlighted. Another advancement is the cyclic nature of the innovation process (Berkhout et al., 2006), where firms have to work with similar processes continuously, learning-by-doing and building capabilities.

Currently, the most comprehensive innovation process model is described and drawn by Caraça et al. (2009), shown here in Figure 2.1.

It is a cyclical model, where the innovation process can begin at any stage within the firm — either in the invention and basic research phase, design or prototyping phase, or perhaps in the commercialisation phase. Therefore, it encompasses both the demand-pull and science-push models, where the catalyst for innovation can come from either creation of new knowledge or from the feel of market demand. The model also depicts feedback loops within every stage within the firm, highlighting the contribution of the third wave of innovation models, especially the chain-linked model by Kline and Rosenberg (1986).

The model illustrates the role of the micro and macro environment and the available knowledge base and market messages. These form a relationship with the firm through interfaces, which can be thought of as the organisational capability to understand its environment (Cohen and Levinthal, 1990). The influence of the fourth wave of innovation models is apparent.

Finally, the model also positions possible outputs of the innovation process. *"The outcome of learning can be either product or process innovations, or the creation of new market segments and new approaches to organise business routines"* (Caraça et al., 2009, p. 864). This is clearly influenced by the Schumpeterian perspective of possible innovation outcomes.

These outputs are in line with the empirical part of this thesis as well. Described in detail in the data section in Chapter 4. In brief, the data used in this thesis also measures these four possible innovations as outputs. Other elements of this

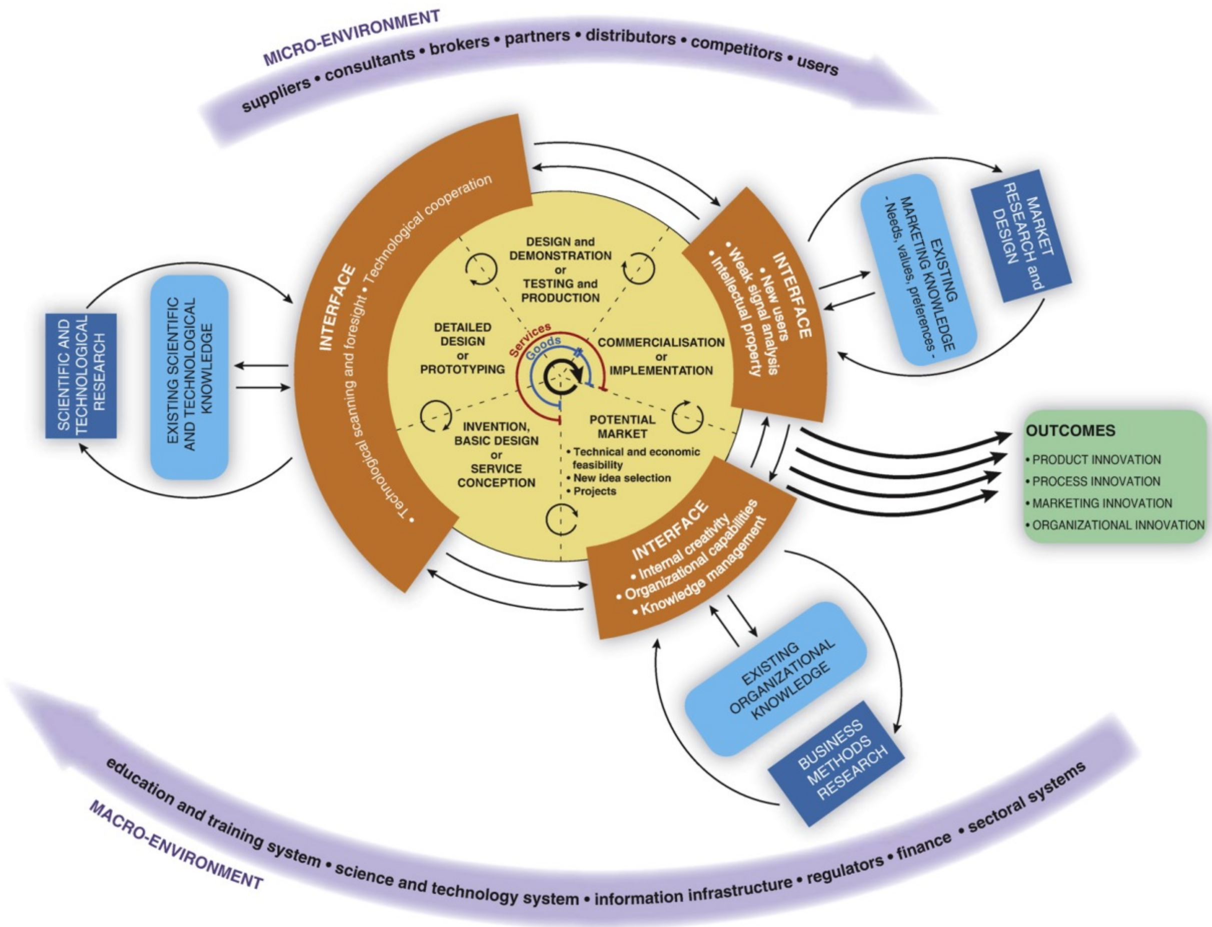

Figure 2.1: The multi-channel interactive learning model of innovation. Source: Caraça et al. (2009)

model are also captured in the data used in this thesis, both micro and macro environment, all three interfaces and the internal processes.

The whole Chapter 2 describes the elements depicted in this model in detail. I will highlight the most important connections briefly starting from the outer layer of the model.

Technological regimes and trajectories are describing the scientific and technological research connection with the firm. The technological trajectories approach highlights especially the role of existing scientific and technological knowledge. Firms have a search mode for new technological breakthroughs, but they are bounded by possible (and most logical) paths. The search for new knowledge is not random. It is guided by what is already available and what are the most reasonable, cost-efficient, or rational options to go forward (Dosi, 1988b). Insights from the technological trajectories and regimes approach imply that firms have some commonalities within economic activities that are based on similar technological levels. These could be what are commonly known as sectors of economic activities (such as NACE), but they may not align.

The interface with the scientific and technological base is dependant on the capabilities of the firm (Cohen and Levinthal, 1990). Since knowledge exchange is not easy nor cheap, it takes time and effort to create a working interface. These concepts are at the very centre of the fourth wave of innovation models, but are also clearly part of the strategic management idea of creating core competences. Without a working interface, the firm is not able to capture the benefits of R&D done outside the firm. It leaves only internal processes, or, as is often the case, firms are not able to keep up with the competition.

Business methods research and organisational knowledge illustrates the role of practices, core competences within the firm, capabilities, best practices, and routines. Scholars in the technological regimes literature tend to describe these as routines and capabilities, and in the strategic management literature as best practices and internal competencies. They both highlight very similar ideas.

Routines and practices are relevant to distinguish why some firms are able to generate new knowledge or understand market needs and other firms are not. In the technological regimes literature, the emphasis is on R&D, how firms organise their operations. However, organisational knowledge also captures other aspects, such as logistics, supply-chain management and internal creativity support. These aspects of organisational capabilities are often discussed in the strategic management literature. Finally, the interface also influences how dynamic these capabilities are. Are firms nimble enough to change their routines and avoid harmful path dependencies? Are they able to absorb best practices?

The third direct link with feedback loops to the firm is market research and design. In essence, it captures the firms ability to understand the needs and preferences of its users. Although it is drawn near the commercialisation phase, the role of users can be influential in earlier phases as well (Hippel, 1986, 1988). The demand driven innovation process emphasises this in full. Firms first try to understand what is needed, then develop based on this (Scherer, 1982).

The interface with market research and knowledge about markets illustrates two aspects: first, the firms' capabilities to understand signals from the market and the firms' clients; second, the firms' ability to appropriate its knowledge from the other side of the market — its competitors. The latter is important since it positions the firm within market forces. If it develops some knowledge about the market and users needs, competitors are also interested in this knowledge, preferably without costs. Intellectual property is a mechanism to both protect and also exhibit this knowledge.

The macro environment is based on large institutions that are guiding our whole economy. In the context of innovation process, these have been noted on both sectoral (Malerba, 2002) and national (Lundvall, 2010) levels. Institutions in this context are *"sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups"* (Edquist and Johnson, 1997, p. 46). Organisations are governing these institutions by providing related services.

An example to illustrate the differences between organisations and institutions in the macro environment for a single firm. The education system as an institution can be described as the propensity of people to learn and exchange new ideas such as the established practices on how teaching is organised, how much the society values education and what aspirations students have. Organisations are schools, the education board or ministries, universities, etc. A firm can interact with schools and universities if it demands knowledge or labour. However, the institutions overall influence whether the firm has any probable partners to even interact with. If educational institutions are very weak, societies are unable to provide the high-skilled workforce which may be needed to attract firms.

Similarly, firms are dependant not only on organisations that finance endeavours. Access to banks, risk capital and other financing schemes are influenced by institutions within the innovation system. If there are weak regulations, lack of trust and enforcement of rule of law, access to additional capital is severely hampered.

The macro environment influences most firms in the innovation system simultaneously. Possible system influence depends on the level of analysis as well. Innovation systems are a framework to think in, not well-defined theoretical models. Therefore, if the analysis of the innovation system is on the sectoral level, there are effects on some industries and not others. For example, the education system could be very well suited for producing high-skilled computer scientists, but not wood chemists. Attitudes and public support as institutions matter a lot in these contexts. If the national innovation system is considered as the level of analysis, a wider picture emerges that depends on access to capital or labour, willingness to take risks, efforts of different organisations to mutually benefit each other or work in silos, and so forth.

An element which is not pictured in Figure 2.1 is STI policies. They are part of the science and technology system (if they exist), and their focus is usually in developing the innovation system. A more detailed description of the scope and ambition of innovation policies is in Section 3. The section also shows that STI policies can influence many organisations and institutions beyond the science and technology system.

The micro environment relates to the firm's ability to engage with potential partners and knowledge sources. These are suppliers, users, competitors, distributors, etc. The list in Figure 2.1 is an example. In reality, firms can have many more potential partners in their micro environment. Extreme examples are like Nokia, a single firm which was the centre for ICT innovations in Finland for a long time (Ali-Yrkkö and Hermans, 2004).

Based on their position in the micro environment, some taxonomies of innovative practices have also been created (Castellacci, 2008; Pavitt, 1984; Pavitt et al., 1989). They highlight various roles a firm can have in the innovation system depending on the relationship with its micro environment. These relationships define the flow of knowledge, sources and partners for innovative activities and new technologies — also the types of activities that are internal and outsourced. The micro environment and the firms' role in it is a major characteristic of how any firm chooses to be innovative.

The internal processes of the firm depend on the available knowledge of new technologies, new processes, market needs, internal capabilities and chosen projects. Potential projects are chosen, developed and commercialised. What is relevant here is the firm's own capability to develop these projects. If firms lack resources in any of these stages, innovative activities may fail. Secondly, firms can develop innovations without going through all the stages illustrated in Figure 2.1. Innovations are often without any changes to core concepts, reinforcing and developing on what is successful in the marketplace (Henderson and Clark, 1990).

The innovation process model encompasses all possibilities for firms to innovate. In reality, most firms skip several of these stages or outsource them to others. The empirical part of this thesis investigates how firms have been creating their innovative strategies. The model presented here allows us to picture all possibilities for any firm.

3. PUBLIC SUPPORT OF PRIVATE BUSINESS

In this chapter, I will give an overview of public support of private business that has been available to firms in Estonia. The chapter proceeds as follows. In section 3.1, I will introduce the necessary context of public support that is under analysis, explain what is lacking in current taxonomies of public policy instrument taxonomies and introduce overarching rationales to intervene in private business. In section 3.2, I will explain the method and the data used to create a new taxonomy of public support. In section 3.3, I will analyse the public support of private business in Estonia and their possible justifications, and will introduce a classification of direct public support based on observations from Estonian firms. In section 3.4, I will explain how these policy instruments have evolved over time. Finally, in section 3.5, I will analyse how these policy instruments can possibly impact the innovation process within the firm.

3.1. Public support, STI context and intervention rationales

Innovation policy, usually incorporated into science, technology and innovation (STI) policy, is wide ranging.[1] These policies cover elements which are supposed to affect both organisations and institutions to create more innovations. *"Innovation policy comprises all combined actions that are undertaken by public organizations that influence innovation processes"*, whether they are intentional or unintentional (Borrás and Edquist, 2013, p. 1513). When the innovation process model presented in Chapter 2 is considered, it leaves ample room for all kinds of activities.

In fact, innovation policy has increased in scope, complexity, policy inclusion and ambition over the last decades (Schot and Steinmueller, 2018). Figure 3.1 illustrates how goals and objectives of STI policies are linked with policy instruments.

Innovation policy is created to fulfil some societal goals, usually derived from political processes. For a long time, the only societal goal for innovation policy was economic growth (Schot and Steinmueller, 2018). However, some developments have been noted in recent decades, where the goal of innovation policy is more aligning with other societal goals, such as clean environment, better healthcare or increased lifespan (OECD, 2015; Robinson and Mazzucato, 2019).

[1] Unless specifically mentioned, STI policies and innovation policy is used interchangeably in this thesis.

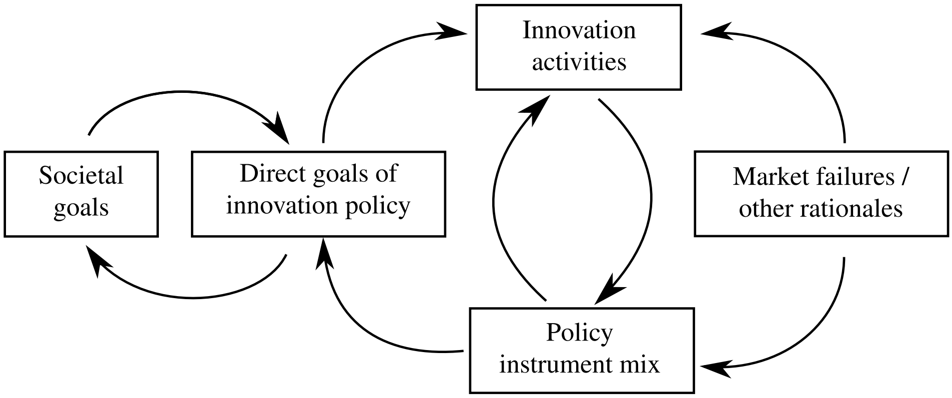

Figure 3.1: Goals, objectives and scope of innovation policy. Source: Borrás and Edquist (2013) and Schot and Steinmueller (2018)

The aim to use innovation policy for transformative change in innovation systems is a rather recent call to arms (Grillitsch et al., 2019; Schot and Steinmueller, 2018; Weber and Rohracher, 2012). Schot and Steinmueller (2018) have framed it as innovation policy 3.0. The most important difference from previous concepts of innovation policy is that the third frame puts more emphasis on societal goals and generating transformative change. The former is easier to visualise, as the goal of innovation policy will become wider to encompass the needs of society better. There is less emphasis on GDP growth, and greater emphasis on inclusive growth. The latter, transformative change, aims to create shifts in socio-technological systems: how we produce, what is demanded by the market, and how to change institutional support systems (Weber and Rohracher, 2012). An example is transformative change in transport. Instead of tackling waste by creating environmentally friendly cars, the aim is to reinvent urban transport by introducing new modes of transport, such as electric scooters.

Since Estonia is not at the forefront of the most innovative of innovation policies that would stimulate transformative change, I will not concentrate on the emerging third frame. Even though the most important difference in how the three waves of innovation policy are categorised by Schot and Steinmueller (2018) stems from societal goals and aims of the policy.

Innovation policy 1.0 and 2.0 have emerged continuously with progress on our understanding of the innovation process within the firm. The first wave has its roots in linear models, emphasising market failures in R&D creation and developing instruments to mitigate such failures. The second wave encompasses elements from innovation systems thinking, pursuing relationships and linkages between knowledge creation, discovery and commercialisation. Instruments in the second wave are wider in scope and application, characterised by systemic failures instead of market failures (Laranja et al., 2008).

The first and second waves of innovation policy have put economic growth at the forefront (Schot and Steinmueller, 2018). The first wave emphasises growth as a direct outcome of R&D, along the lines of growth visualised by Vannevar Bush (1945). The second wave goes wider in sources for economic growth, but does not change the underlying goal. In Figure 3.1, the main societal goal is GDP growth in both innovation policy 1.0 and 2.0. Although, there is an opposing view to the notion that previous research and agenda setting in innovation policy has given thought only to GDP growth, calling the argument a bit offhanded (Giuliani, 2018).

Direct goals of innovation policy are set based on innovation activities, expressed in innovation terms. In the innovation policy 1.0 framework, direct goals are grounded in R&D activities, either expressed as expenditures, engaged personnel, outcomes like patents and inventions, or variations thereof. In the innovation policy 2.0 framework, things are a bit more complicated. The most famous example is the attempt to gather the direct goals of innovation policy into a single index, the European Innovation Scoreboard (Hollanders and Es-Sadki, 2018). The measures aiming to describe the direct goals of innovation policy in the Innovation Scoreboard include PhD graduations, access to venture capital, R&D expenditures, scientific publications, SMEs introducing product innovations to the market, public-private-co-publications and high-tech exports, among many others.

Innovation activities (that are under investigation by researchers) have, therefore, also widened in scope. Since the first innovation process models, our understanding of them has evolved (as described in Chapter 2). More and more innovation activities are taken into account, and, if needed, policy actions are determined. Innovation policy instruments and the justifications for their creation are illustrated on the right side of Figure 3.1.

The most important breakthrough in understanding that led to the first wave of innovation policy is that R&D has qualities akin to public goods (Arrow, 1962; Nelson, 1959). Markets fail when positive or negative externalities are not included in the final price of goods or services. Knowledge, once created, can distribute freely and cannot be used up. Firms face appropriation challenges if their proprietary knowledge can be used by competitors without bearing the development costs. Without correction, there are disincentives for societal investments in R&D. The rationale for intervention in R&D creation is, therefore, that if society is not willing to bear some of the costs, firms are not willing to start innovative activities. We would not even know what we are missing.

The first wave of innovation policy instruments were actively seeking problems with R&D activities. Hence, the first wave of instruments also deal only with R&D creation and diffusion.

The second wave of policy instruments include the national innovation system framework thinking which emphasises relevant institutions and organisations that have influence over innovative activities within the economy (Edquist and Johnson, 1997; Klein Woolthuis et al., 2005; Lundvall, 2010). Relevant actors include firms and whole industries, universities, competitors and financial institutions (banks, venture capital). Institutions such as education systems, legal frameworks, financial systems (regulations, attitudes), standards and norms also qualify, to name a few. The national innovation system framework has been successful as a tool to discuss interlinking aspects and influences of innovation in economies with policy-makers.

Recent descriptions of possible instruments to influence economic and innovative activities in the realm of science, technology and innovation policy have also adapted the national innovation system framework. Examples can be found on the EU level (Izsak, Markianidou, et al., 2013), in research papers (Dolfsma and Seo, 2013; Edler and Georghiou, 2007; Georghiou, Edler, et al., 2014) and policy reports (Izsak and Edler, 2011). This is a top-down perspective in which firms are one agent among many. The innovation system perspective is good for policy formulation; it helps with understanding possible interactions between institutions and the creation of policy mixes (Borrás and Edquist, 2013).

There has been a widening and deepening of innovation policy instruments (Borrás, 2009), meaning that innovation policy accounts for a more diverse set of actions, especially outside the focus of R&D. Secondly, innovation policy has become more linked with other policy spheres.

This widening can also be thought of as representing an emerging hierarchy within STI policies (Lundvall and Borrás, 2006). Science policy deals with the creation of scientific knowledge. Technology policy deals with advancement and commercialisation of technical knowledge. Finally, innovation policy deals with the overall innovative performance of a country. The latter remains the context for this thesis as well. Innovation policy is considered to be much wider than just the creation and diffusion of scientific or technical knowledge.

It is also relevant to emphasise the scope of instruments that can arise from this delineation. What Lundvall and Borras (2006) effectively show is that innovation policy has the widest set of policy instruments compared to technology or science policy, due to its overarching focus.

Besides R&D, rationales for government intervention with policy instruments evolved beyond market failures. Within the STI domain, there are multiple arguments for justification of intervention, possible instrument mix and objectives (Laranja et al., 2008). Other rationales are explained via system and institutional failures, and failures to link elements of the innovation system for cooperation, a coordination or network failure.

A review of past research done by Klein Woolthuis and colleagues (2005) categorises the justification rationales for innovation 2.0 into a framework of eight system imperfections or failures. These are infrastructural, transition, path dependency, hard and soft institutional, strong and weak network and capabilities failures. Infrastructural failures are related to the physcial infrastructure that actors need to function. Transition, path dependency and capability failures refer to actors that are unable to transform themselves, either by lacking the necessary knowledge or support.

Hard and soft institutional failures and strong and weak networking failures are related to institutions which are either not supportive or not evolving. Hard institutions typically include legal systems, intellectual property rights systems, standards and norms, etc., while soft institutions include culture, attitude, tolerance to risk, social values, and so forth. Networking failures are related to problems of coordination, when firms have either too close links and miss out on outside opportunities (strong networks) or they are unable to coordinate (weak networks), which leads to an absence of complementarities.

Hard and soft institutions described above relate to formal and informal arrangements affecting an organisation's performance. These can be measured as institutional quality, which enables comparison of the conditions across innovation systems. The quality of institutions is one of the most important aspects of economic growth (Acemoglu and Robinson, 2012). In the innovation systems framework, conditions such as financial environment, incentives for innovation, standards and norms, and appropriation conditions are all relevant for SME development and innovative activities (Kuhlmann and Arnold, 2001; Lundvall, 2010). If there are negative incentives, unclear regulations or other externalities hidden in, for example, intellectual property legislation and application procedures, it can result in lagging competitive advantages for firms. Institutional failures can be viewed both as forms of market failure and systemic failure (Laranja et al., 2008).

Based on Estonian innovation policy instruments, I will refer to market failure-based rationales as innovation policy 1.0 rationales and systems thinking failures as innovation policy 2.0 rationales. This will inform the categorisation of rationales for justification with policy instruments. Innovation policy 1.0 and 2.0 rationales can co-exist simultaneously, as is often the case.

Current taxonomies of innovation policy instruments cover both innovation policy 1.0 and 2.0 instruments and rationales (Borrás and Edquist, 2013; Edler, Cunningham, et al., 2016; Edler and Fagerberg, 2017; Edler and Georghiou, 2007; Izsak, Markianidou, et al., 2013). When contrasted with the supposed relationship between science, technology and innovation policy instruments (Lundvall and Borrás, 2006), they cover all of them. However, to consider the variation within the public sector support given to firms, in monetary terms, these taxonomies are not detailed enough.

The European Commission report on innovation policy instruments includes direct business innovation support, consisting of support given to product development, marketing, commercialisation, services innovation, innovation management, industrial design, support to innovation readiness, acquisition of machinery, equipment, know-how, and promotion of internationalisation (Izsak, Markianidou, et al., 2013, p. 88). All these are presented within one category. Clearly, many of these activities can have more or less influence on the overall innovative output. Furthermore, this taxonomy is one of the most accommodating when considering monetary support to firms which is given under different policy domains.

Edler and Georghiou (2007) and Borrás and Edquist (2013) both consider mainly R&D instruments in their taxonomies of innovation policy instruments, leaving little room for technological upgrading or commercialisation efforts. When most firms are probably creating incremental innovations rather than radical innovations, it can be too narrow to consider only R&D based instruments as innovation policy tools.

Edler and Fagerberg (2017) and Edler, Cunningham, et al. (2016) develop a classification based on policy goals which also aligns with the objectives in this thesis. However, they aim to give an overview of large groups of policy instruments, therefore classifying very broad categories that can have overlaps. Their classification is useful when the whole (national) innovation system is under analysis.

For this thesis, the main focus is on direct support to firms. This means that firms are directly influenced (treated) by the policy instrument. Indirect effects, such as changes to institutions and actors above the firm level, are not under analysis.

There are three reasons for limiting this thesis to policy instruments where firms are direct recipients of treatment. First, sectoral and national level instruments affect all firms simultaneously at the corresponding level. Second, there is no way to disentangle which firms did not get treated by indirect effects of policy instruments. For example, if policy instruments are aimed at creating a more entrepreneurial culture in the IT sector through awareness campaigns in universities, delineating firms by sectoral classification is probably not appropriate. Third, since the main interest in this thesis is the effect of policy instruments on firm innovation strategies, the unit of analysis is also the firm, not the innovation system.

Due to the focus of this thesis, the lack of detail in current taxonomies of policy instruments and above reasoning, I develop a new classification of innovation policy instruments which emphasises direct public support to firms. The aim is not to classify all possible innovation policy instruments, but only those which are directly given to firms, usually expressed in monetary terms.

Going back to the focus of STI policies by Lundvall and Borrás (2006), policy instruments analysed here can actually be found under all of them. There are R&D instruments under science policy, such as grants for conducting R&D. There are labour force training and skill development instruments under technology policy. There are organisational development instruments and clustering instruments under innovation policy. All these apply, since they are directly given to firms. However, instruments like competition regulation, standardisation and norm creation, intellectual property rights regimes and higher education reforms are out of scope in this new classification.

The taxonomies of innovation policy instruments that have been described above are too broad in their categories. Hence, if only one type of instrument is under analysis (direct support to firms), then there is a possibility to look further into this category. A deeper analysis can also give insights into what supported actions are more related to firm innovativeness. For example, in the Edler and Fagerberg (2017) taxonomy, all direct support falls within one category. However, there may be differences in outputs if direct support is in the form of technology acquisition or R&D activities support. In fact, the analysis in Chapter 7 shows just that.

This is not meant as a critique to the taxonomies currently found in the literature. Their focus is to describe all possible innovation policy instruments within the innovation system, targeting all actors and institutions. However, in this thesis, there is an opportunity to look at instruments targeting one specific group of actors, namely firms. Within this narrower scope, there is room to distinguish between different supported activities and instrument types, which is not realistic due to comprehension limitations on the whole innovation system level.

Direct business support, which is usually categorised into a single group among policies targeted to SME development, such as offering advice, training, best practices, networking and marketing assistance, exporting information schemes and other soft services, are found in almost all OECD countries (OECD, 2000). These are all relevant for innovation policies as well, if they encompass the whole range of STI.

There are several overarching economic rationales for policy intervention in the STI realm to explain why some markets are not functioning in a way that produces maximum welfare to society. These are general cases which can be seen in various specific areas. Usually policy instruments have more narrow reasonings which are derived from these general market failure or systemic failure arguments.

Intervention to R&D is mostly justified by the market failures argument. In other policy domains, similar reasoning about intervention rationales can be seen, e.g. transport (Docherty et al., 2004), energy (Jaccard, 1995) and environment (Reinhardt, 1999). Economic arguments for government intervention revolve around societal welfare such that if the market system does not reach its maximum, a rationale for intervention exists. This argument is an umbrella for all types of interventions.

Markets can fail when information asymmetries exist (Akerlof, 1970). The general solution would be to reduce the cost of information, which then delivers a trade off between cost and efficiency. Information asymmetries can be relieved, for example with quality assurances to buyers.

Markets also fail when positive or negative externalities are not included in the final price of goods or services. One example is R&D itself, which has qualities akin to public goods (Arrow, 1962; Nelson, 1959). Similarly, production processes often have negative externalities in generating waste in the local environment. If these are not priced in, the burden of cost is allocated to society, while consumers receive discounted goods.

Market control over competitors can also yield results that are not optimal in society. For example, monopoly powers tend to reduce production capacity to increase profits while creating a dead-weight loss in society. Examples to reduce anti-competitive behaviour in firms under regulation are more than a century old. In the US, the Sherman Antitrust Act was created in 1890 to reduce the effects of dominant market power.

Besides market and institutional failures, inefficiencies in business management is a third relevant element in direct business support (Lattimore et al., 1998). Inefficiencies in business management are visible in the long tail of productivity distribution (Andrews et al., 2015; Bloom and Van Reenen, 2007; Syverson, 2004). Although differences can be seen in institutional quality, management practices and policy reactions across countries, a significant portion of badly managed firms exist. Gearing attention towards this long tail instead of market leaders could arguably benefit society in the long-run (Haldane, 2017).

There seems to be no lack of good rationales to argue for policy intervention in the private market. Market failures, systemic failures and management failures offer possibilities for a wide range of instruments. In this context, direct support for firms will be taken into focus. Based on empirical observations from Estonia, direct business support is categorised into classes which highlight the activities support with instruments.

The rest of this chapter describes how this classification is created, the main results, how it relates with innovation policy 1.0 and 2.0 rationales, and finally, which innovation activities these instruments are supposed to affect when the innovation process model presented in the previous chapter is reintroduced.

3.2. Method and data description to develop a classification of direct business support

Sabatier (1986) compared and analysed top-down and bottom-up approaches to policy analysis. The top-down approach is more useful when analysts wish to consider a single program or a single policy, especially when there are single powerful actors involved, for example, on government agency overseeing the whole policy field. In contrast, the bottom-up view is more appropriate when there are multiple actors involved without specific power-dependency. In addition, the bottom-up view is more appropriate when the analysis investigates the dynamics of actor interactions in a specific policy sector.

Based on the seminal work of Sabatier (1986), the classification created in this chapter also takes the bottom-up view. Since innovation policy instruments have been under the auspices of many local policies, this approach is more useful. Direct business support can apply to actors involved with science, technology and innovation policy, environmental policy, social policies or agricultural policy. In general, the use of various actors as tools for public policy has increased (Salamon, 2002), especially since there are actors involved who can be either public, private or non-profit in delivery networks (Blair, 2002). As can be seen later, this also true in the Estonian case.

In the bottom-up view, there can be overlaps in activities supported. To classify the possible interacting instrument mix, direct business support has to be dissected into categories from the bottom up rather than top down. Otherwise, it would mean that there is an *ex ante* choice of policies and instruments which can represent direct business support. I believe that this *ex ante* decision cannot be made in reality, since that would mean that researchers would also be aware of all possible instruments that a sample of firms has been a part of before the analysis is done. It is a case of unknown unknowns.

I start this bottom-up view on the possible choice of instruments from the firm perspective, meaning instruments which are directly geared towards the firm, whether to create incentives or disincentives for certain behaviours. These can be direct funding of behaviour, e.g. buying machinery, training of workers in the firm, or being part of consultancy programs.

I make no distinction between specific or general policies (Freitas and von Tunzelmann, 2008). Policy instruments can be given to firms in specific sectors or to any firm that applies. I also make no distinction between tangible or capacity building policies (Schneider and Ingram, 1988). Instruments may involve strong incentives, e.g. costs are eligible only if they reduce emissions by some percentage, or the firm may use funds as it sees fit, more akin to voucher programs.

Policy instruments that firms cannot apply to are out of scope. This includes policy instruments which are general in the innovation system, e.g. reforming middle school education to include more science and technology education. Of course, the latter also affects firms in the long run, but indirectly. Therefore, the instruments covered here should be ones that the firm can either apply to or take part in directly without applying.

This classification is a taxonomy, i.e. empirical classification generated by quantitative identification (Peneder, 2003). Instruments are classified according to their similarity. The resulting classes are polythetic, meaning that the instruments within one class are not identical in every dimension. This is natural, since policy instruments also evolve over time, and the activities they wish to promote undergo major and minor tweaking, but their overall goal can stay the same.

Empirical observations of direct business support have also one major drawback — they have to be observable. Most direct supports that involve money are counted and documented with precise care, especially public sector money. However, many types of direct public support are actually allocated indirectly. For example, a firm manager may receive training in a publicly funded workshop targeted to managers. Funds can be paid directly to the organiser of the workshop based on a headcount of participants. However, this headcount, the number of people who actually participated and their identity, is documented on paper in an archive. Who has not seen a registration sheet at a seminar on a table near the entrance, waiting for signatures? The information on these papers is more often than not unobservable. Therefore, the use of instruments, or rather the treatment by different instruments, is underestimated with an accounting perspective based on different registries. Even so, the instrument might aim for direct business support and is paid for by the public.

Figure 3.2 shows two possible paths of following direct business support. The upper path is observable when both direct support and treatment come from the public agency simultaneously. The lower path is often unobservable in full. Direct support to the treatment provider is accounted for and publicly available, but their actual provision of treatment is not. For example, when a business incubator gets a subsidy for five years, the amount per year and total is readily observable in public registries and in the treatment provider's annual report. However, the data on how many firms actually had incubation services and how successful they were, is not

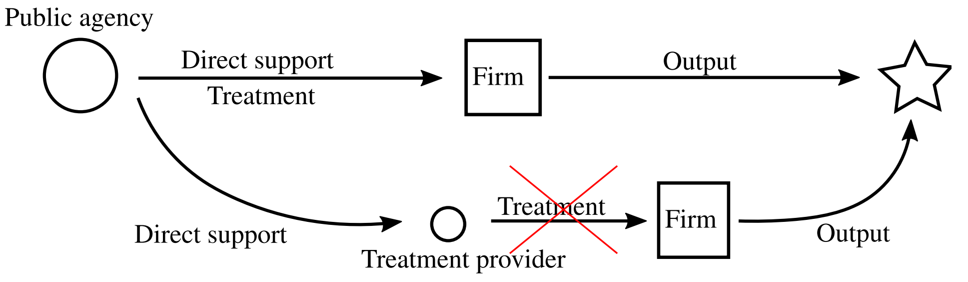

Figure 3.2: Observable and unobservable paths of direct business support

available or easily accessible. Generally, we are interested in who has received treatment, not funding recipients.

Thirdly, inspired from the taxonomies exhibited in Edler and Fagerberg (2017), Izsak, Markianidou, et al. (2013) and Edler, Cunningham, et al. (2016), the classification is based on supported activities. These are shown as the objectives of instruments, which determine the main category of classification. For example, whether they are to give consultancy or funds to acquire machinery. Policy rationales also align with supported activities. A step further from these taxonomies is the sole focus on direct support. Where these taxonomies have a single instrument, direct support to R&D and innovation, the new classification will be able to explore effects within such categories. When policy strategy documents or legislation has no indication for justification rationales, these are estimated from similar instruments found in the literature.

Finally, the allocation of instruments to different classes is based on document analysis. For every public instrument where multiple firms are affected, there is legislation available. Regulations usually state policy aims, supported activities and eligibility criteria for costs and beneficiaries. Policy strategy documents and development plans also state the purpose, aims and sometimes supported activities. If none of these are available, titles of actual projects within the instrument are used to estimate supported activities.

A lengthier description of data sources used in this thesis is in Chapter 4.2. A few short notes are given here as an introduction.

Data about direct business support instruments comes from all relevant public agencies on the local and national level in Estonia between 2001 and 2016.

Two public agencies, Enterprise Estonia and Agricultural Registers and Information Board, are the main paying agencies dealing with both large firms and SMEs. Both have supplied their full register of all business support given to beneficiaries, including project titles, relevant instruments, sum of money and dates.

The EU structural fund register is also combined into the dataset. These include many of the larger projects, some infrastructure projects and instruments geared towards other organisations such as workshop or training providers. This register is available since 2004.

In addition, Estonia's State Aid register has been scraped. In 2007, Estonia transposed EU competition regulations into Estonian law and set up a digital State Aid register. All Estonian state aid and *de minimis* aid is tracked through this register. EU competition policy has strict state aid rules, and exemptions have to be notified and are monitored. All aid must be approved by the European Commission, fall under block exemptions or be under *de minimis* aid limits. The maximum amount of *de minimis* aid currently allowed is 200 000 euros per undertaking over any period of three fiscal years. Since many direct business support instruments are low in sum, a balance of payments is kept for every beneficiary in the register. Also, there are examples in this register where aid given to firms is indirect, to be calculated afterwards. For example, when workers have been retrained in a public program, the cost of the program is not payed directly to the firm, but it has been estimated and kept on balance in the firm's state aid or *de minimis* aid total sum. This is one, and probably the best, way to observe the treatment of instruments where funds have not been paid directly to the firm — to observe the unobservable path.

The structural funds register and state aid register add another 20 public organisations that have been giving direct business support over the years. The main paying agencies are the Environmental Investment Centre, Technical Regulation Authority, Ministry of Economic Affairs (only very large projects directly), Ministry of Finance (also large projects), Estonian Unemployment Insurance Fund, and some specific foundations for R&D support and loan guarantee services for SMEs.

This data covers direct support given to businesses, non-profit organisations and public enterprises. Instruments specially meant for public organisations, e.g. local governments, are not included.

Most of these instruments provide direct support for which firms have to apply themselves. Many instruments operate within specific sectors, are limited in access to firms of a certain size or age, and specify conditions for eligibility criteria. Since direct support is an input to innovative activities, or, at the very least, firms are opportunistic in relieving budgetary constraints in their entrepreneurial activities, this taxonomy is based on supported activities. From the firm perspective, instruments can then be considered as inputs to the activities that these instruments wish to promote. If needed, these supported activities can be taken to the innovation system level. However, with some instruments, relevant institutions and the direction of input between institutions cannot be recovered on the innovation system level.

This data covers the information about which instruments were used by firms in this thesis.

Policy instruments, their rationales and supported activities are covered in strategy documents and legislation. These can be found on the web pages of agencies involved, call documents for policy instruments themselves, in the national legislation web page Riigiteataja or from ministries' web pages, where national strategy documents are hosted.

Altogether, 113 different policy instruments and their documents were analysed to create this classification. A list of all policy instruments classified in the taxonomy is in Appendix I

3.3. Classification of direct business support in Estonia

Following is a description of 11 business support types that can be distinguished from empirical observations. Table 3.1 on page 67 highlights all classes with a short description. Table 3.2 on page 69 highlights all classes with possible intervention rationales.

Collaboration programmes are instruments to support R&D or modernisation projects in cooperation between competitors, industry and academia, or several academic institutions. Mostly, these are international projects with partners from several countries. The policy aims of these programmes are to increase university-industry collaboration, increase technology transfer and exchange of knowledge between universities and industry. Also, they aim to promote cooperation between universities and local governments across borders. Widely known examples of instruments in this category are the EU Framework Programmes for Research and Technological Development, the latest of which, FP8, is known as Horizon 2020. Other examples are the EU Interreg programmes and local programs such as the Estonia-Latvia science exchange programme.

Open innovation takes advantage of knowledge inflows and outflows to accelerate the innovation process (Chesbrough, Vanhaverbeke, et al., 2006). Under-investment in collaborative efforts to perform innovative activities has negative consequences for firm innovation performance (Laursen and Salter, 2006). The reasons for these under-investments can be expressed in terms of market failures. Three specific market failures related to information asymmetries reduce the incentives to undertake collaborative innovation activities. These are: (1) firms' lack of understanding of potential benefits of open innovation or can not estimate its potential outcomes; (2) firms' inability to estimate the potential capabilities of their partners; and (3) firms' limited information about the trustworthiness of potential partners (Hewitt-Dundas and Roper, 2018). From the innovation system perspective, this would mean that there is an interaction or network failure (Weber and Rohracher, 2012).

The potential benefit for firms participating in open innovation is increased innovative performance. Nambisan and Sawhney (2011) identify four private benefits of open innovation: (1) firms' reach for new ideas, markets and technologies is increasing; (2) the cost of innovating is reduced; (3) the risk of commercialisation is reduced; and (4) the speed of development is increased. Firms participating in these instruments should indicate internal or external R&D performance, links with other actors in the innovation system and new products or processes in the piloting stage.

Consulting instruments are subsidies for hiring external experts for firm diagnostics, creating development plans and other types of consultancy. Generally, they are project and domain based, short-term assistance. The distinguishing characteristic of consulting instruments is that they are limited in term and are designed for offering advice on best practices.

Consultancy is an experience good (Nelson, 1970). Buyers cannot assess beforehand whether the advice they are getting is good. This implies that there may be an information asymmetry problem with consultancy, leading to a suboptimal purchase. Firms are not able to evaluate whether the advice they are getting is generating positive returns. To compensate, a reduction in the fixed cost of purchasing advice can be justified. An EU commissioned report on business support service relating to the provision of information and advice found four main categories where markets can fail (Atherton et al., 2002): (1) adverse selection of business advice services through information failures; when information has (2) public good or (3) mixed good qualities; and (4) when information has externalities.

There may be transaction costs for searching and participating in consultancy, especially for SMEs (Lattimore et al., 1998). Managers have to invest considerable time, which can have high alternative costs, especially if firms are small and managers have multiple roles within the firm.

Consultancy programs can range from very technical to general management practices and according to policy domain. STI policies deal with intellectual property, agricultural and industry policies deal with best practices, and environmental policies deal with reducing pollution. Consultancy instruments include, for example: engaging development consultants in product design, commercialisation or international marketing; industrial design and patenting applications; forestry development plans and best practice hotlines; and manufacturing and supply chain management.

Training instruments are intended to increase innovation or entrepreneurship related skills. These are often aimed at business managers, researchers, workers and interns, both blue- and white collar. Training and skill development programs are widespread and fairly low-cost instruments.

Training and skills development programs are similar to consultancy programs. Consultancy offers external advice, a tangible knowledge, whereas training is a method to pass on intangible knowledge. Possibilities for market failures in both remain fairly similar. There are high search costs and difficulties in distinguishing quality service providers *ex ante*, and service providers are not generally long-term partners. Under-provision of training in the workplace also occurs if workers are too short-sighted to expect future higher wages or if firms are afraid of renegotiation of wages after the training (Brunello and De Paola, 2004). Also, if the training is general enough, firms are reluctant to invest for fears of poaching (Becker, 1993).

Policy domains range horizontally between policies and subfields. On the policy level, for example, there are STI policies for developing entrepreneurship skills in creative industries and regional policies for worker retraining programs to reduce structural unemployment. On the subfield level, instruments differ between sectors, as can be seen by specific training programs for agricultural industries, local government workers or technical fields. Examples include general training programs for young workers in specific fields; business plan development training for freelancer designers; international training programme reimbursement for engineers; general manager training programmes to increase awareness of innovation capabilities and benefits of innovative activities; open calls for firms to reimburse worker training costs, etc.

Marketing and export promotion support instruments for planning and executing marketing activities can vary between commercialisation efforts, export realisation efforts and plan development. The distinguishing characteristic is the aim to increase visibility of current products and reduce the costs of entering new markets.

Lattimore (1998) identifies seven possible market failures to justify policy interventions: (1) reputational externalities; (2) knowledge transfers from overseas leading edge customers; (3) externalities from knowledge about new markets; (4) adverse business attitudes to exporting; (5) ignorance of benefits of exporting; (6) capital market imperfections; and (7) tariff compensations. Market failures 1 to 3 are about the externalities of exporting. Learning by exporting is a hypothesised effect whereby firms can gain new knowledge and enhance productivity and innovativeness after becoming an exporter. Exporting firms have higher productivity (Bernard and Jensen, 2004). But whether it is due to knowledge spillovers from exporting activities or because firms with higher productivity self-select into exporters has been debated for some time (Clerides et al., 1998; De Loecker, 2007, 2013; Salomon and Shaver, 2005). The latter arguments 4 to 7 of protectionism legacy in business culture or on tariff compensation are not very convincing. At least in the European union context, there seems to be no case made for either.

A more realistic argument would be that the cost of information about new markets is expensive. Firms with high capital constraints are not willing to pursue possible new markets without knowing the possible return on investment. Business development agencies are willing to cover some of the cost by acquiring knowledge about other markets, developing contacts and networking. The social cost of acquiring this knowledge is shared and is smaller than it would be if all firms develop this knowledge on their own. Such knowledge is passed on with policy instruments to beneficiaries. The market failure for firms would be an uncertainty of return on their investment. This, compounded with a lack of skills about market penetration, can be a high burden for firms. If their first strategy for exporting is not correct, they may feel that there is no second chance.

Policy domains can cover STI policies, regional policies, industry policies or local entrepreneurship development policies. Examples include support to develop marketing plans for export markets, subsidies to visit or present at trade fairs, and joint marketing events for businesses abroad.

Innovation and R&D instruments enhance innovation competences and support investment in research and technologies. This class of instruments combines several supported activities together that may have very fuzzy boundaries or are often eligible within the same instruments.

The first type is pure research instruments, where firms can reduce the cost of basic or applied research and apply for external funding. These can often be demand-side instruments, where new knowledge is acquired through procurement schemes. The support of basic or applied research in the material technology sector and applied research support in Smart Specialisation fields are two examples.

The second type is innovation and development voucher instruments. These are small lines of credit for firms to either gain knowledge about whether their development idea has enough potential for further investment or to purchase services from other providers to develop their innovative product to market maturity. Examples are innovation voucher instruments, R&D voucher instruments and support for reducing costs in developing pilot projects.

The third type is specific grants for firms to develop new products or services. These grants are evaluated by public agencies. When approved, beneficiaries are eligible to cover costs of production and present a product in due time. An example from the creative arts sector is film grants, where small production firms compete for a grant to cover the development of a full feature firm. Other examples are firm based grants based on committee evaluations with individual funding rules, specifically: grants to develop an ICT based language teaching tool; defence sector grants for developing patriotic games and film media; and grants to support specific services like major concerts or art shows.

The fourth type is specific product development or SME support instruments, where the aim of the instrument is to create new products or new firms with innovative products. These can be individual or group efforts involving multiple firms. Examples are: agricultural grants for firms to develop additional products or services which are not in their main field of business activities, to diversify their business portfolio; grants to develop tourism products in specific regions; support to firms to reduce costs while cooperating with technology development centres; and the EU LEADER instrument where local communities invest in local products and services.

The rationale for public support of R&D, as already explained, is due to the prevalence of positive externalities which lead to suboptimal investment in society. Laranja et. al (2008) explain possible rationales for public intervention in STI policies in the context of different economic theories. These range from possible market and institutional failures to cognitive and learning failures. Since this class of instruments is already defined by the STI perspective, possible rationales are diverse. Rationales themselves are also defined by policy goals. For example, if there is a goal for optimising resources in society and a need for market failure correction, a simple reduction of cost is needed. If there is a goal to create a complex and highly functional cluster of innovative industries in some region, the policy rationale for intervention tends to become more comprehensive and various.

Innovation and R&D instruments here cover basic and applied research and product development. This is only a part of possible STI instruments. Product development itself is a nuanced process which entails decisions on concept development, supply chain design, product design, performance design and validation, and production and launching (Krishnan and Ulrich, 2001). There can be possible rationales for intervention with even more specific instruments in all these processes. Therefore, it is evident that possible policy domains are diverse.

Innovation and R&D instruments are not always part of STI policy, but can stem from agricultural or regional policy domains as well. If product development is involved, it can be part of developing new industries, for example, the creative arts. Disentangling of innovation and R&D instruments is also difficult, because often the same instruments can cover early pre-competitive development and application or commercialisation costs. To disentangle and analyse the possible effects of innovation and R&D support separately, a finer distinction has to be made on the project level.

Investment instruments mainly support the modernisation of physical capital. In essence, these could be a fifth category of innovation and R&D instruments, but they are so prevalent that they merit their own category. The commonality between investment and innovation and R&D instruments is their likely output. Since process innovations are a frequently estimated type of innovations, most upgrades of infrastructure or manufacturing machinery within the firm should yield some improvements in working processes. Therefore, most investment instruments likely yield innovations and could be counted as an innovation and R&D instrument.

However, besides their popularity, three more considerations are in favour of establishing a distinct category. Firstly, investment instruments can be differentiated in their scope. Their cost eligibility rules state only buying new machinery or betterment of firm infrastructure, such as buildings, roads or ICT. These instruments are aimed at purchasing investment goods, not development based on investments. For example, investing in R&D infrastructure like laboratory equipment is an investment, not R&D itself. Secondly, most of these instruments are designed for laggards in technology, to increase productivity based on available technology which can be purchased. These are aimed at supplier dominated technological trajectories (Castellacci, 2008; Pavitt, 1984). Instruments for which firms develop their own machinery would be included in the innovation and R&D category. Thirdly, this is not only the most popular category of instruments, but also the most costly, especially in Central and Eastern European countries where Structural Funds are available. Transition and development economies play catch-up with national or supranational support.

The rationale for investment instruments to subsidise private capital in the form of machinery and equipment supposes that investments increase productivity growth in a way that social returns are higher than private returns (De Long and Summers, 1991). De Long and Summers (1991) suggest that the relationship between investment and productivity growth is causal, and social returns on investment are around 30 percent per year. There is a critique that this relationship is not general enough (Blomstrom et al., 1996), and emprical results on this topic are mixed. There are positive findings, zero effect and mixed findings when only EU policies are concerned (Brandsma et al., 2013). There are also findings that possibly allocation and policy failures are at fault for the lack of positive results in capital subsidising (Bergström, 2000).

The rationale for investment instruments in Central and Eastern Europe comes mainly from EU stated goals of improving regional competitiveness and employment, promoting economic growth and convergence, and European territorial cooperation (European Commission, 2017). A full list of possible expenditures in the EU Cohesion Policy includes 86 items from all conceivable policy domains (Ferrara et al., 2010).

Investment instruments are diverse in policy domains. STI policies include investment instruments for firms and research facilities for innovation capabilities. Agricultural policies include investment instruments for productivity and innovation increases. Environmental policies include investment instruments for reducing waste and compliance with environmental regulations. Social policies include investment instruments for developing infrastructure in health care facilities, education facilities and special need care facilities. Specific local government policies include investment instruments for local supply service infrastructure needs, like power grid investments, water supply, long distance heating or waste treatment. Regional policies include investment instruments to target specific laggard regions. In fact, the list is endless in possibilities. For countries with an extensive business support infrastructure, there are examples for investment instruments in most sectors.

Examples of investment instruments are acquisition of new machinery; investment in transport infrastructure; acquisition of environmentally friendly machinery or waste reduction systems; investments in R&D infrastructure like laboratories or piloting facilities; reduction of cost for utilising antiquated infrastructure; acquisition of new farming infrastructure; modernisation of sea vessels for transport or fishing; investments in ICT infrastructure; reduction of cost for purchasing electric vehicles.

Mixed support includes instruments where support activities are varied within the instrument or are not clearly defined. Most of the instruments in this category are early phase mixed support instruments. These are direct business support aimed at start-ups or newly created SMEs. Early phase instruments allow for a variety of different activities simultaneously, such as reducing cost for first product development, acquiring some technology, marketing and visibility efforts and skills development. At the same time, these instruments are fairly low-cost per beneficiary, typically ranging around 15 000 euros. Mixed support also includes incubation instruments, where firms receive several types of services at the same time. Therefore, there is no reliable way of making sure what the actual supported activities are to every beneficiary under these instruments. Typical examples in this category are start-up support for newly created ventures, a lump-sum type instrument, e.g. support to participate in business incubators.

New venture creation and growth relies on financing capabilities (Aghion et al., 2007). There is a financing gap between young firms and banks and private equity lenders (OECD, 2011), because they have no collateral and their prospects are risky. The recent financial crisis exacerbated this gap, furthering the gap also between young firms and venture capital (OECD, 2011). Early stage funding market failures come mainly from information asymmetry problems (Wilson and Silva, 2013).

Information asymmetry is due to young firms' inability to signal their capabilities, as they have no track record and no internal funds. This may lead to social costs where many new ventures are just not created, a so called ”missing markets” problem. Secondly, young firms have positive spill-over effects to society at large, creating an ecosystem of entrepreneurial spirit, venture capital funding and start-up creation. This has externalities which lead to economic growth and job creation (Kerr et al., 2010).

There is also some evidence that small-scale support to venture creation can act as a hidden labour market programme, which turns previously unemployed into employed in a untypical form of single-purpose business which may be outside the scope of labour laws (Román et al., 2013). Hence, there may arise a new market failure after mixed support instruments, which creates new forms of self-employed who do not aspire to be entrepreneurs in the long-term. Policy goals are usually depicted to create entrepreneurs akin to Schumpeterian market destroyers. The implications for policy are stricter selection processes for new entrepreneurs (Santarelli and Vivarelli, 2007; Shane, 2009).

Mixed support instruments also involve instruments to more mature SMEs. The services offered are similar to early phase development, but they are aimed at firms with an already developed product or service. The general aim is to develop the firm to a ”new competitive level”. This may include some form of technological upgrading, training, marketing efforts or consulting. It is similar to the idea of creating national champions, just at a very micro scale. This may also include a national goal type effort, where firms get mixed support to develop their processes to meet new regulatory standards. For example, to reduce waste while processing a product, mixed support instruments can assist with training, R&D, acquisition of machinery, idea generation or legal efforts.

Mixed support instruments, especially early phase development instruments, exist horizontally and vertically in different policy domains. There are national development plans for new venture creation, but also local government development plans for fostering entrepreneurship. These instruments can be very similar in their eligibility rules, scope and funding, but they originate from different levels of governance. Horizontally, there are specific instruments in ICT, agriculture and industry. Also, there are horizontally competing instruments available in social or labour policies, where unemployed are re-trained and given initial capital to form new ventures. If there are overlaps in geography and possible fields of activities, beneficiaries can shop around for more relaxed rules, bigger funding and governing bureaucracy.

Labour support instruments are subsidies and direct monetary support for creating new jobs and hiring workers. In labour support instruments, firms are remunerated for hiring and maintaining labour, essentially reducing their cost of labour. Several distinct types of instruments are within this category.

Firstly, firms are remunerated for hiring underprivileged workers. These can be long-term unemployed, workers with disabilities or workers with special assistance needs. Mostly, these instruments fall under social or regional policy domains to increase labour participation generally or in specific areas.

Secondly, firms are remunerated for creating jobs. These are essentially social, regional or industry policies to increase labour participation rates and persuade firms to open new ventures in specific places. For example, firms can recover 50 percent of the cost of labour for 1 year in newly created jobs. A special case of this type are sector based instruments, where firms recover part of the cost of labour based on their amount of workers overall. For example, flag of convenience policies provide shipping firms with direct business support based on the number of workers on boats annually.

Third, internship and training support based on labour participation provides firms with remuneration for some of the cost of hiring interns. There are examples based on the number of interns hired and based on the cost of mentors.

Fourth, improving working time quality overall is a rare type of instrument whereby firms can apply for direct support to improve the quality of working conditions by introducing rules of conduct, ethics, support to unionisation, manuals and other rules or guidelines. In essence, quality of working life improves when workers are more aware of their rights, obligations and rules pertaining to their work. Improvements of physical infrastructure regarding working life quality does not fall under this type of instrument.

In this category, instruments are aimed at increasing labour market participation rates in some specific geographic areas or for some specific parts of the labour force. Factor immobility is a classic argument of market failures. Industry and labour immobility both have adverse effects for competitive equilibrium. However, if factors of production can freely move between firms, there may be limits for creating competitive advantages (Peteraf, 1993). Without them, firms may under-invest out of fear of not appropriating results.

Market failures may arise also from labour market discrimination. The crux of the issue is whether firms pay relatively lower or higher wages to certain labour groups based on some non-economic characteristics which do not affect labour productivity. Therefore, if this is true, the labour market is inefficient. Total output seems to be unaffected by standard economic models of labour discrimination, suggesting that various signalling methods like licences, education and tests should be enough (Cain, 1986). Still, as Cain (1986) acknowledges, many forms of discrimination are not based on any economic reasons, thus economists may ignore these effects.

Information externalities in labour markets refer to lack of information about workers' productivity. If there is non-economic discrimination towards some disadvantaged groups and economic discrimination towards others, it may be beneficial to lower the cost of hiring. For example, long-term unemployment can reduce workers' overall motivation and abilities enough to create lasting effects in reduced wages over a lifetime (Arulampalam, 2001). Disabled workers receive smaller wages overall and have smaller labour market participation rates (Jones, 2008). If the cost of the policy is smaller than other forms of assistance for these groups, it can increase labour market participation, increase total output and reduce social costs at the same time.

Financial guarantees are a form of funding assistance. They are generally a form of indirect funding, where state actors alleviate some of the risks of private capital raising. Policy domains are usually for entrepreneurship but can range in sector specificity. The most common instruments provide loan guarantees and sureties to firms when they apply for funding from commercial banks. The typical example is guarantor services for SMEs.

A special case of instruments under financial guarantees are national insurance instruments. These are compensations in the case of catastrophic events, loss of agricultural yield due to wildlife, and loss while hosting major cultural events. A typical example is remuneration to beekeepers for bear damage.

This is similar to market failure in regard to new venture creation. There are information asymmetries in signalling capabilities, so financial markets are not able to assess risks with enough due diligence. The public sector therefore provides guarantees to cover some of the costs, thereby negating some risks.

Direct subsidy or operating aid instruments are cash transfers for specific, often national, goals. Two types of instruments are categorised together. The first is regarding instruments where business support is not tied to any specific activity, but is based on the output of the firm, meaning that the aim of direct support is to boost the possible output in quantity. This can be, for example, direct business support to other agencies providing some sort of treatment to firms. They can use this money in their day-to-day activities, but there is no expectation that they will change their behaviour because of it. Therefore, it is a direct subsidy to their budget, and no treatment effect is expected. Typical examples are NGOs that provide training to workers, support to creating or maintaining professional associations, and support to NGOs through the EU LEADER scheme which acts as a local liaison.

Secondly, firms that are acting on behalf of some specific national interests can receive direct subsidies to reduce the cost of their operations. At the same time, they do not demand any upgrade in service quality, innovativeness or productivity. A typical example is remuneration for post firms to operate last-mile routes, and direct support to regional airports to cover their operating costs.

Policy domains are mixed in this category. Often, specific instruments are created for one-time instruments based on firms' and current needs. Operating aid can often be found in areas where private firms do not wish to operate and state enterprises fulfil national goals.

The second category of direct subsidies to firms should entail some qualities of public goods or quasi public goods. There is no need to go into details in this paper about whether some typical examples in this category such as postal services or infrastructure projects should be privatised. There are good arguments on both sides. What is relevant, though, is that this type of direct support to businesses is often observable in an accounting perspective. How these finances are earmarked or made available for use is based on auctions or other mechanisms specific to certain fields. For example, in support to local airports, there is hardly a case for auctioning to build new ones. For postal services, many regions are bundled and auctioned separately.

The first category is more interesting as a business support subsidy. In general, this is a type of demand-side policy instrument where public sector procures services to be handed out in society. Evidently, there are market failures involved, since the public sector needs to offer these services. The question is whether these services were provided before to firms with a higher price or were not provided at all. In the former case, this is a reduction in price to overcome some market failures, such as information asymmetry or externalities. This depends solely on the project involved. In the latter case, there is a problem of missing markets. These services were not provided in this region at all.

In any case, this category mostly falls under the unobservable path in Figure 3.2 if we wish to understand business support. Often the recipients of direct subsidies are treatment providers. We can be aware that some business service is provided, but we are not aware of who actually benefits.

To conclude, all 113 policy instruments which were analysed have been classified into these 10 categories. A summary is presented in Table 3.1 on page 67. Naturally, some of these are much more popular among firms and widely used, while others are rare. The same goes for their costs, as all categories are dwarfed by investment instruments.

It is evident that direct business support instruments can have interaction effects between different possible supported activities. It is also evident that firms can be a beneficiary in multiple instruments at the same time. This is especially apparent when policy domains are overlapping, policy goals are supposedly achieved with similar instruments, and when firms are opportunistic while shopping for state aid.

To understand whether these policy instruments have any effect on firm behaviour, we have to rule out possible altering effects from other instruments. In most empirical papers about policy instrument treatment effects, there may be a serious case for omitted variable bias. The number of possible policy domains that should be covered and datasets simultaneously compared is large.

A simple investigation within the dataset analysed here revealed the existence of firms that received business support simultaneously, in at least 5 categories of this taxonomy within the span of two years. Further research will uncover details on firm preferences and the types of instruments most likely to be applied to concurrently.

The small descriptions given above about possible policy domains and governance levels suggest that there may be many interaction effects at play on the policy level as well. For instance, for early phase, mixed support, there are many policy level interactions possible where a single firm in a specific region could fund its new venture from four different funds simultaneously.

These interaction effects can come from STI, agricultural and environmental projects, and so forth. Simultaneously, they can come from all possible levels of government, from local to supranational. Firm behaviour can be altered by incentives to reduce waste or energy use, which can be subsidised by environmental policy instruments. These effects are still visible as possible process innovations, but they are not part of formal STI policy. Therefore, our own scope as researchers should be broader when considering policies that alter innovation performance. This is especially true if we wish to investigate possible treatment effects empirically with real world data.

The classification analysed and presented here will be used as a basis for empirical analysis in further chapters. Without creating this classification, more than 90% of policy instruments would have been within one overarching category if wider taxonomies of innovation policy instruments found in the literature would have been used. The classification created here highlights some of the differences that can be found in the realm of direct business support and grants, where firms are direct beneficiaries.

Table 3.1: Taxonomy of direct business support

Activities supported	Description	Rationale
Collaboration programmes	Science or industry programmes to foster collaboration and create networking effects. Ex. EU INTERREG programmes, producer group creations, technology competence centre programmes.	Lack of awareness; limited information on functional capabilities; limited information on trustworthiness
Consulting	Subsidies for hiring external experts for firm diagnostics, development or consultancy. Project based short-term assistance. Ex. Subsidies for hiring designers for a specific product, experts consult production line specifics.	Asymmetric information about quality; high transaction cost of participation; positive and negative externalities
Training & skills	Training and development of labour within the firm. Programs for visiting workshops and new skill development. Ex. Subsidies for worker retraining programs, subsidies for learning design management.	Asymmetric information about quality; high transaction cost of participation; positive and negative externalities; appropriation of training investment
Marketing & export promotion	Support for planning and executing marketing activities, individually or grouped. Ex. Subsidies to develop marketing plans for export markets, subsidies to present at trade fairs.	Possible positive externalities; social cost savings
Innovation and R&D	Subsidies to create new products, new services, development and other activities aimed at fostering new ventures. Also innovation vouchers and awareness schemes (if they promote new ventures directly). Ex. Subsidies for new environmentally sustainable services, subsidies for creating new products (manufacturing and creative arts), subsidies for R&D projects within firms.	Positive externalities; catalyst of long-term networks; new industry development

Continued.

Activities supported	Description	Rationale
Investments	Policies mainly to establish, enhance and modernise physical capital. Ex. Subsidies to co-fund investments for new machinery, subsidies to construct necessary infrastructure.	Positive social returns
Mixed support	Start-up or early phase development. Includes various activities or services, such as incubation. Also, small cash-transfers for new ventures. Ex. Subsidies for starting ventures for first investments, subsidies for participating in incubation programs.	Asymmetric information about abilities; capital market failures; positive externalities; spill-over effects to entrepreneurial ecosystem
Labour support	Subsidies and support for creating new jobs, hiring underprivileged groups, developing and maintaining internships. Ex. Subsidies for hiring workers with disabilities.	Factor immobility; information externalities; cultural discrimination
Financial guarantees	Sureties and guarantees provided for loans.	Asymmetric information about abilities; capital market failures
Direct subsidy	Cash transfer funding for specific (national) goals. Also, emergency funding for state enterprises. Ex. Remuneration for postal companies for last-mile services.	public goods; quasi public goods; missing markets

Table 3.2: Intervention rationales for direct business support

	Innovation policy 1.0				Innovation policy 2.0				
Instrument type	Information asymmetries	Appropriation failures	Externalities	Inefficiencies in business management	Infrastructural failures	Transition failures	Institutional failures	Network failures	Capabilities failures
Collaboration prog.	x			x		x		x	
Consulting	x			x			x		x
Training & skills dev.	x	x		x			x		x
Marketing & export	x		x	x					x
Innovation & R&D	x	x	x		x	x		x	x
Investments	x		x	x	x	x			x
Mixed support	x		x	x		x	x	x	x
Labour support	x						x	x	
Financial guarantees	x		x	x		x	x	x	x
Direct subsidies		x	x		x				

3.4. Evolution of entrepreneurship and innovation policies in Estonia

In this section, I will give a brief overview of public support to private business in Estonia between 2002 and 2012. As already discussed in Section 3.1, STI policies can be wide in their policy domains, covering many other policy fields as well or have overlaps. In the relevant literature, scholars usually talk about STI policies or innovation policy in general. In policy documents and national development plans, policy makers might have opted to call it something else. Therefore, I will introduce the evolution of innovation policy in Estonia and how relevant policy instruments have changed. These instruments have been within different policy domains and are found in different development plans enacted concurrently. These are the main development plans which are responsible for instruments that have been classified in Section 3.3.

A brief description of the evolution of these instruments and development plans will also clarify why we see more intensive use of instruments in latter periods, and also why the range of instruments have become wider during latter periods. Results from the data can be found in Section 4.2.

In this section, I will emphasise the evolution of policy and instruments which is aimed directly to firms. As in Sections 3.1, 3.2 and 3.3, the focus is on instruments for which firms are beneficiaries. Instruments aimed at other actors in the innovation system or institutions are mentioned only briefly.

Main development plans related to public support of firms and fostering entrepreneurship are shown in Figure 3.3. These are the main policy documents responsible for economic growth and entrepreneurship policy. Estonia's knowledge-based development plans include R&D and higher-education policies.

Estonia joined the EU in 2004. Access to EU Structural Funds, and inclusion to Cohesion Policy and Common Agricultural Policy meant that new development plans had to be created. This is the reason most development plans end in 2006 and start again in 2007. They are aligned with EU programming periods for easier operation with policy funding.

The first relevant national development plan is found in the general principles of the Estonian export policy[2], ratified in the Parliament in 2001 (Riigikogu, 2001a). This development plan set the stage for many other economic growth or entrepreneurship support plans in the future. The general principles of the Estonian export policy emphasised the need for high-tech exports and support for SMEs. Therefore, there should be some sort of picking winners strategy for specific sectors, and large firms are not the focus of the policy.

[2] Eesti ekspordipoliitika põhialused.

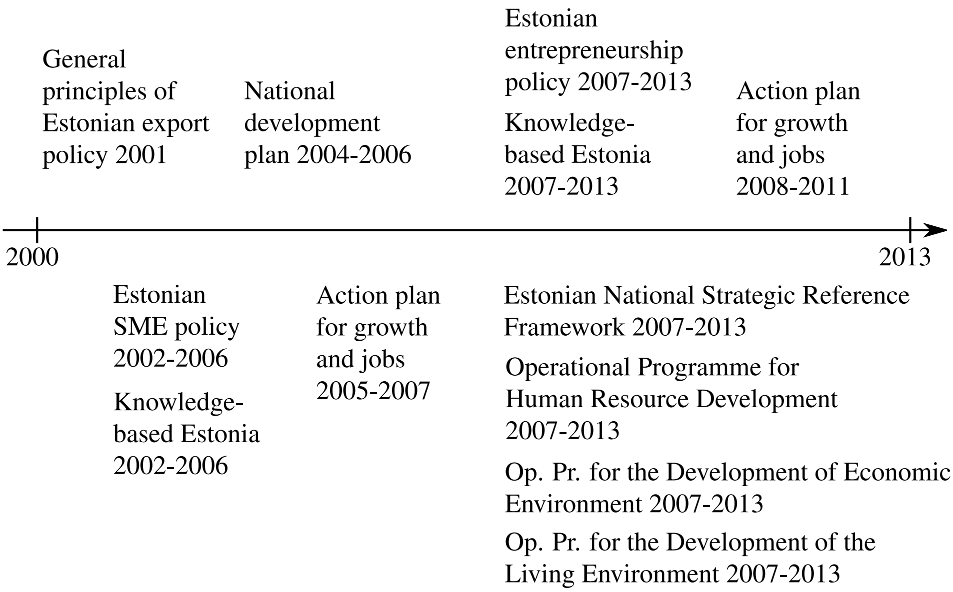

Figure 3.3: Main Estonian development plans related to public support for firms.

Two main policy instruments are put forth: export guarantee programs and export support programs. The first is a national insurance program for importer defaults. The second is support for visiting trade fairs, developing export plans, consultancy in finding new markets, visiting trade fairs, export promotion events, and other similar instruments. These are fairly low-cost and aimed at promotions or skill development. Low brand recognition of Estonia and Estonian products and lack of skills in exporting are two main obstacles for entrepreneurship highlighted in the first export policy development plan.

The first entrepreneurship policy development plan[3] was an SME policy (MKM, 2002). The main goals are to foster an entrepreneurial spirit, new job creation and increase competitiveness, all mixed with balanced regional development. The main focus is on SMEs, and there will be no discrimination between business sectors. It can be said that there have been attempts to pick business sectors in Estonia that are to be nationally developed as champions, but there has never been any political consensus long enough for it to stick. Many development plans indicate that there should be a focus on high value-added sectors or high-tech, but it has rarely been enforced on the policy instrument level.

The SME plan had two focus areas which are relevant here — human resource development and development of financing capabilities. Three other focuses are

[3] Ettevõtlik Eesti. Eesti väike- ja keskmise suurusega ettevõtete arendamisele suunatud riiklik poliitika 2002-2006.

dealt with infrastructure development for entrepreneurship, awareness campaigns and reduction of bureaucracy.

Still, the main obstacles are lack of capital and skills. Human resource development instruments included consultancy instruments and training instruments. Financing development included guarantees for SMEs, new venture creation assistance (lump-sum), investment aid and additional assistance to high-risk projects. The latter instrument never materialised in reality.

The first R&D and innovation (RDI) policy is called Knowledge-based Estonia[4] (Riigikogu, 2001b). RDI policy set forth two major goals — advancing the knowledge base and increasing the competitiveness of firms. Key business sectors or areas in focus were user-experience driven IT solutions, bio-medicine and material technologies. This was also the first time when Parliament ratified a goal to increase total spending on R&D to 1.5% of GDP (from ca 0.75%). The aim was to first increase public spending on R&D in order to stimulate private spending on R&D. Current total spending on R&D in Estonia is at 1.3% (2017).

Most instruments in the RDI policy were aimed at the public sector, specifically to public universities. Funding was provided for infrastructure, machinery, collaboration networks, etc. For firms, the major instrument was co-financing for R&D projects. All other instruments aimed at firms were really indirect, for example, awareness campaigns for innovative activities or training of university R&D staff for spin-offs, collaboration and industry needs.

This is the first period for policies in Estonia that had a solid development plan behind them and had specific goals and instruments put forth. Before these, most instruments were haphazard and divided between a large number of public sector foundations. A foundation reform also took place during this era and gathered most policy instruments into two main bodies for entrepreneurship support — Enterprise Estonia (EAS) and KredEx. The former deals with support instruments, the latter with financial guarantees.

Estonia had a relatively small budget at this time for public support. Before the era of EU funding, there were not many instruments, and there was not much to hand out. All the instruments mentioned here, which were directly aimed at firms, had a total budget of less than 13 million euros between 2001 and 2004 (Praxis, 2007). That covers the R&D projects, new venture creation, consultancy and training instruments and export development programs. Financial guarantees had a total of about 83 million euros during the same period (Praxis, 2007).

[4] Teadmistepõhine Eesti. Eesti teadus- ja arendustegevuse strateegia 2002-2006.

After the EU accession, Structural Funds became available in Estonia. To access this funding, Estonia created a national development plan[5] (Eesti Vabariik, 2003). This laid out plans for all policy areas where EU funds could be used including economic affairs, social affairs, environment and agriculture.

Entrepreneurship policy combined both entrepreneurship instruments from the SME policy and RDI instruments from Knowledge-based Estonia. There were not many additions to the instruments themselves, but the availability of EU funding increased the budget significantly. If before 2004 these instruments received in total about 13 million euros, then between 2004 and 2006 the budget was around 97 million (of which 73 million was from the European Regional Development Fund).

Table 3.3: First period of Estonian entrepreneurship and RDI policy instruments (2002-2006)

Activities promoted	Instruments
Business development	Aid for new venture creation; Consultancy & training; Export plans & market research; *Awareness campaigns for entrepreneurship*
Business infrastructure development	*Establishing business incubators*; *Physical infrastructure*
Promotion of RDI	R&D project co-financing; *Research centres*; *R&D infrastructure and technology transfer*; *Awareness campaigns for innovation*
Tourism	New product development; Marketing support; *State promotion*

Note: Instruments whose beneficiaries are not firms themselves are in italic.
Source: (Eesti Vabariik, 2003)

The first period of instruments is summed up in Table 3.3. The main instruments are: lump-sum aid for new venture creation, consultancy and training; export plans and market research support; R&D project co-financing; and product development and marketing support for tourism companies. There are some cases where firms also get investment aid, but these are under physical infrastructure instruments, e.g. new facilities or communications in or near the factory, or R&D infrastructure, where it is possible to buy new machinery or technology. However, in this period, the latter is not very common.

There were some policy goals to increase networking at the time as well. However, all instruments were geared strictly towards public research institutions and universities, for them to increase their knowledge base and become more attrac-

[5] Eesti riiklik arengukava Euroopa Liidu struktuurifondide kasutuselevõtuks - Ühtne programmdokument 2004-2006. (Eesti k. tuntud kui riiklik arengukava ehk RAK).

tive in turn as a partner to the private sector. The general aim of these policies was to increase the competitiveness of firms and increase employment. By competitiveness, it is implied that Estonian firms will become better at exporting, which is supposedly the main source of economic growth. The period from 2001 has been the first time since Estonia started to have a co-ordinated entrepreneurship policy with strategic aims, governmental support and initiative (Kuura, 2006). However, it still remains mostly an SME policy.

In 2005, the European Council approved the Growth and Jobs Strategy, where EU heads of state agreed that each Member State should create an action plan to promote economic growth and job creation. In Estonia, this was called the Action Plan for Growth and Jobs 2005-2007 for the implementation of the Lisbon Strategy[6] (Eesti Vabariik, 2005). It was mostly a continuation of previous development plans without much progress. The main arguments were still lack of access to capital and lack of entrepreneurial skills, and the main focus was on SMEs.

In general, the Action Plan focused more on the instruments that involve other actors and institutions in the innovation system, such as higher education, science base, entrepreneurial spirit and awareness, demand of skills, etc. The Action Plan was also much more optimistic than reality has proven to be. For example, the document as accepted by the Estonian government declares that public expenditure on R&D shall exceed 1 percent of GDP in five years and 1.2 percent of GDP in 10 years. The public expenditure of R&D in Estonia was around 0.4 percent of GDP at the time.

From the Action Plan where this goal is stated: *"The guiding principle of the government has been to set realistic and achievable goals and guarantee their fulfilment. Therefore, its goals are based on conservative estimates"* (Eesti Vabariik, 2005, p. 25). During this time, there was very high economic growth and optimism. This is visible even in national strategic documents. In reality, Estonia has never reached the 1 percent goal of public spending on R&D. This indicates that some of the planned instruments and budgets were actually never allocated. Some instruments never opened, even if they were put forth in development plans.

To sum up, the first period of instruments started to develop from the early 2000s and continue without much changes until 2007. There was a slow increase in funding during this period, and the portfolio of instruments slowly grew wider, as policymakers developed them. Most of them had their first rounds around 2002 and 2003. After 2004, when EU funds became widely available, budgets increased substantially.

[6] Eesti majanduskasvu ja tööhõive tegevuskava 2005–2007 Lissaboni strateegia rakendamiseks.

The second period of policies in Estonia all started with 2007 to match the EU programming periods for funding. The main development plan is the Estonian Entrepreneurship Policy 2007-2013[7] (MKM, 2006). This policy was developed further in 2010 under the same name[8]. The RDI policies were in the Knowledge-based Estonia development plan[9] (HTM, 2007).

In addition, there were four development plans which were written to conform with EU rules to access EU funding. This was very important at the time, since the national budget had limited possibilities. These were the Estonian National Strategic Reference Framework[10] (Eesti Vabariik, 2007d) and the operational programmes for human resource development (Eesti Vabariik, 2007b), economic environment (Eesti Vabariik, 2007c), and the living environment (Eesti Vabariik, 2007a)[11]. These development plans set forth how most instruments were funded that are described as a national policy.

The main barriers for entrepreneurs were relatively similiar to the previous period (MKM, 2006). Firms, especially new ventures, lack access to finance, while entrepreneurs lack skills to innovate and internationalise. Lack of cooperation between firms as a possible barrier to growth was recognized as a new concept, although system instruments to support cooperation ventures did not follow at first.

The main instruments for Estonian entrepreneurship policy between 2007 and 2013 were continuations and developments of previous ones: trainings and skill development; consultancy; access to capital through loans, guarantees or lump-sum support for SMEs and new ventures; and export planning, market research instruments, marketing instruments for exports, and business missions.

Furthermore, the 2007-2013 period budget was significantly higher than the previous period. There were a few new instruments available to firms which became the most important ones in Estonia. To support technological catch-up, there was an understanding that not only entrepreneurs need to know what is possible (consultancy and training), but they also need a boost in acquiring new technology. Old investment instruments provided support for certain infrastructure near firms, such as communications or access. New investment instruments provided support to acquire new technology or machinery.

[7] Eesti ettevõtluspoliitika 2007-2013.

[8] I thank Kaupo Reede from the Ministry of Economic Affairs for pointing this out and providing both versions from their archive.

[9] Teadmistepõhine Eesti 2007-2013, vahel Teadmistepõhine Eesti II.

[10] Riiklik struktuurivahendite kasutamise strateegia 2007-2013.

[11] Inimressursi arendamise rakenduskava 2007-2013, majanduskeskkonna arendamise rakenduskava 2007-2013, elukeskkonna arendamise rakenduskava 2007-2013.

The second major change was that entrepreneurship policy was no longer an SME policy. Most of the budget went to support internationalisation, acquisition of new technology and training instruments, which were available to all firms. The target group for a lot of the instruments therefore became wider. Often, the same instruments had several calls and separate budget allocations to cater to SMEs and large firms separately.

Knowledge-based Estonia developed RDI instruments simultaneously. The main goals for firms were aligned with the entrepreneurship policy — higher productivity and more exports. The latter is still seen as the source for economic growth.

Compared with the previous RDI policy, public sector research facilities and universities are now seen as competent enough to cater to entrepreneurs. The focus for entrepreneurs has shifted more towards co-operation support with universities, both local and international, and support for applied research. Some instruments continued from the previous period, such as support for R&D projects, spin-offs, creation of business incubators and research centres, and some new instruments were also created. These include: support for hiring or training R&D personnel; consultancy and firm diagnostics instruments; awareness and training in intellectual property rights; market research for new technology; business cluster support; seed-funding and early-phase support for technology-intensive start-ups; and finally, acquisition, testing and prototyping new technology.

Instruments in the entrepreneurship policy and RDI policy had some overlaps and catered to the same target group. In general, there was a widening of instruments, as many more new activities were funded. Also, the target group was wider than in the previous era.

The Estonian National Strategic Reference Framework which indicated how EU Structural Funds were planned in the programming period 2007-2013 was aligned with the Estonian entrepreneurship policy and Knowledge-based Estonia programme in full. The barriers for entrepreneurship highlighted were all the same as can be found in other programmes. Subsequently, the instruments described were the same as well. Estonia's policymakers figured that if these documents are aligned, national policy can be made with EU funding.

The policies involved in these programmes targeted new business sectors as well during the second period, such as sectoral targeting for the creative industries (Eesti Vabariik, 2007c). Instruments were designed to promote new ventures, innovations, marketing and awareness of entrepreneurship in creative industries.

The operational programme for human resource development (Eesti Vabariik, 2007b) detailed instruments involving hiring, training, skill development and consultancy. Foundations had been laid in the entrepreneurship policy and RDI policy plans. More activities were now involved with the supply side as well, such as instruments to develop consultancy programs themselves and train better consultants.

The third pillar of programs from the era, the operational programme for the development of living environment (Eesti Vabariik, 2007a), had less direct support to firms. Since the third pillar contains also local municipal infrastructure investments for resource efficiency, we can observe some of the effects in the data of this thesis. These are essentially investment instruments where the main goal is better resource management, better waste management or other types of efficiency. Firms that are beneficiaries can be seen as purchasers of new technology. Thus, these instruments are parallel to the entrepreneurship policy instruments where firms acquire new machinery and new technology.

Table 3.4: Second period of Estonian entrepreneurship and RDI policy instruments (2007-2013)

Activities promoted	Instruments
Capabilities and skill development	trainings; skill development; consultancy; internship support; management training programs; mentoring programs; *awareness campaigns*
Investments	SME grants; loan guarantees; micro-loans to SMEs; investment support for new-technology and machinery acquisition; infrastructure investment support
Internationalisation	export guarantees; business missions; export planning and marketing; industry-fair visits; market research; support for business networks; *state promotion; FDI promotion*
RDI	R&D project support; acquisition of new technology; promotion of spin-offs; *research centres; awareness campaigns; cluster programmes; R&D co-operation programs*
Sector specific	tourism product development and marketing support; new venture and innovation programs in creative industries; *state promotion; awareness campaigns*

Note: Instruments where beneficiaries are not firms themselves are in italic.
Source: Eesti Vabariik (2007a,b,c,d, 2008) and MKM (2006, 2010)

The second Action Plan for Growth and Jobs[12] for the period 2008-2011 was also created (Eesti Vabariik, 2008). It lists 6 goals for the development of entrepreneurship and innovation. However, they are a rehash of policies and instruments already described in the Estonian entrepreneurship policy, Knowledge-based Estonia and the National Strategic Reference Framework. Almost all instruments described therein are also planned to operate between 2008 and 2013, which spans

[12]Eesti majanduskasvu ja tööhõive kava 2008 - 2011 Lissaboni strateegia rakendamiseks.

outside the development plan itself anyway. A positive aspect of the Action Plan is that it further codifies the main policies and instruments.

Table 3.4 highlights the portfolio of direct business support in Estonia for the period 2007-2013. The portfolio has become wider, it has significantly larger budget, and it caters to a wider target group of firms. As can be seen, many of the instruments have continued from the first wave. Barriers and possible solutions have remained relatively stable since 2004.

Outside assesors to the entrepreneurship and RDI policy pointed out some potential problems during these periods as well. Estonian R&D funding had duplication issues, where two different councils both promoted similar projects, thereby creating fragmentation issues (Nedeva and Georghiou, 2003). This created potential bridging problems between basic research and applied research funding. Both councils were united only in 2012 into the Estonian Research Council.

By 2007, a shift from the supply of R&D to strengthening the demand of R&D by private firms is suggested (Polt et al., 2007). However, many of the suggested policy instruments never manifested. Still, the shift from undersupply of public research capabilities to attention to private firm capabilities was noted. This is also clearly seen in the type of instruments deployed afterwards.

To conclude the overview of Estonian entrepreneurship policy and RDI policy instruments between 2001 and 2013, there can be made a few summarising points. Firstly, the core set of instruments have been relatively stable over this time. Secondly, there has been a shift from SME financial support to business development in the form of investment support and growth (capabilities and recruitment) support (Männik et al., 2011). Possible financing mechanisms have been diverse throughout the period. There are loans and loan guarantees available, direct lump-sum support, and also indirect support to intermediaries for business services (Männik et al., 2011). Finally, a vast increase in the budget allocated to the instruments can be seen throughout these years.

I believe this overview of entrepreneurship and innovation policies in Estonia provides enough insight to make it clear how the classification created in Section 3.3 came to be. Policy instruments available in Estonia have become as diverse during this period as can be seen from the classification. Data and examples of uptake is in Section 4.2.

A final note remains to be made on entrepreneurship and innovation policies regarding agricultural policies. These have been concurrent to the policies described here. Two development plans are relevant during this era — the Special Accession Programme Agriculture Rural Development (SAPARD) 2000-2006, Rural

Development Programme 2007-2013[13]. I have opted not to include these in the overview here for three reasons. First, Estonian entrepreneurship policy acknowledges the existence of rural development plans, but their goals are not aligned, and development plans have little overlap. Second, there is little overlap between firms in both policies. Third, the firms in the sample used in this thesis do not include agricultural businesses, policy instruments from the rural development plans are basically not observed. For these reasons, the inclusion of policies aimed at developing agricultural businesses seems to be excessive in this thesis and would create more confusion than understanding of the issues at hand.

3.5. Interaction between public support and firm innovation process

Section 2.6 concluded with how the innovation process within the firm can take place along with its relationship with the innovation system. Public support to firms aims to remove some barriers in order for this process to take place, or at least accelerate it. Therefore, most innovation policy instruments are also directed towards some specific actions within this innovation process. This section describes what aspects of the innovation process within the firm are affected by the instruments categorised into a classification based on supported activities.

In general, it is possible to describe three types of additionality of policy instruments - input, output and behavioural additionality (Buisseret et al., 1995). Investigations into input additionality examine whether public policy instruments have the effect of generating or increasing inputs to the innovation process, such as R&D expenditure (Czarnitzki and Lopes-Bento, 2013a, 2014). Input additionality evaluates whether policy intervention creates inputs that would no be there otherwise. Output additionality examines whether public policy instruments increase or generate outputs in the innovation process, e.g. increased innovativeness (Czarnitzki and Delanote, 2015, 2017; Czarnitzki and Hussinger, 2018). Measured innovation outputs are generally patents, innovations (products and services), revenue from innovations, etc.

Behavioural additionality deals with differences in the behaviour of firms after intervention (Buisseret et al., 1995; Falk, 2007). It is not a very specifically defined concept, and it can range from instant on-off changes of behaviour to long-term persistent change in R&D and innovation activities (Gök and Edler, 2011). Georghiou and Clarysse (2006) differentiate between strategic and operational behavioural additionality. In this thesis, most of the data used is more on the strategic level of innovative activities according to this model, but these levels

[13]SAPARD - liitumiseelne programm esimese Maaelu Arengukava koostamiseks, järgnes Maaelu Arengukava (MAK).

are not differentiated. It would create another layer of complexity to the investigation of dynamics of firm innovation strategies that has limited payoff. Gök and Edler (2011) also separate evaluations of behavioural additionality into four categories based on coverage and persistence. The topics covered in this thesis are related most closely to their third category, which covers both R&D activities and innovation activities in general and looks at the persistence of effects.

An overview of results from different OECD countries suggests that there are positive effects to company behaviour after government R&D funding (OECD, 2006). Positive changes include more willingness to collaborate with external partners, changes to commerical strategies, long-term R&D strategy planning and execution, and subsequent and extended innovation activities beyond the initial project.

To describe the possible effects of policy instruments, the concept presented in Chapter 2, Figure 2.1 is used as a basis. Since there are many different types of policy instruments included in the taxonomy created in this chapter, the model is redrawn in a different form to facilitate the addition of policy instruments. The underlying concept is the same but repurposed. The final result is presented in Figure 3.4 on page 83, which shows the possible effect of innovation policy instruments as a description of inputs, i.e. what type of input the policy instrument is to the innovation process. Further investigation into this process will look at both outputs of this process (Chapter 7) and behavioural changes (Chapters 8 and 9).

There are four major areas of the innovation process in this model which can be influenced by policy instruments. These are within the firm, in interfaces with existing knowledge outside the firm, with the micro-environment and the macro-environment.

Training and skill development and labour support instruments are the only instruments shown to affect the innovation process solely within the firm. These instruments raise the level of expertise of workers and management for better performance of the innovation process. That is not to say that these instruments cannot have an effect that is also linked with other actors in the end, but rather these instruments train people to perform better themselves. With labour support, it is the reduction of personnel cost that can aid in any within-firm process.

Innovation and R&D, mixed support, and marketing and export promotion instruments all influence the firm and the interface at the same time. Mixed support instruments offer both training and skill development type activities, and also link firms with best practices from others. For example, in incubators, firms are taught new skills, but they are also networking with others to gain knowledge about possible paths for growth.

Innovation and R&D and marketing and export promotion instruments are both also on the fringes between a within-firm type of instrument and creating interface links. They are differentiated by what interfaces they operate on, one for external R&D knowledge and the other for marketing knowledge.

Collaboration programmes are an interface promoting instruments mostly in the R&D part. In innovation policies, they aim to bring together industry and academia in general. Business cluster instruments could be operating in more interfaces than R&D, since they aim to enhance co-operation between industry competitors. Possible benefits are also stronger marketing efforts and exchange of best practices.

Consultancy instruments are a good example of a policy that promotes the interface between the firm and existing knowledge. In Figure 3.4, consultancy instruments are duplicated in every interface. There are examples of teaching about best practices for management, marketing, export markets, design, technology, supply chains, etc. In essence, consultants can be used in all possible business areas.

Investments and direct subsidies forge a direct link with the micro-environment by creating incentives to engage with other actors, mostly suppliers of new technology and machinery. These instruments provide new investments to the firm by which the innovation process within the firm also changes. For example, a new machine for production also changes the work process as a result. However, the main link is through relationships with the micro-environment.

Direct subsidies can also have within-firm effects by creating new processes without investments, for example, when there are open calls for services which the firm did not offer before. With direct subsidies as a financial incentive, firms can begin to provide these new services to the market without outside assistance.

Financial guarantees are a type of instrument that alleviates market failures within the larger financial system. Therefore, they operate on the boundary of the innovation process by reducing information asymmetry costs for capital providers. This is the only type of instrument where firms are direct beneficiaries, but the possible direct effect involves the whole firm. In essence, we have no indication on which part of the innovation process the additional capital has been allocated, but we can only estimate that firms receive financial means that were not available before.

As Figure 3.4 indicates, innovation policy instruments are inputs to the innovation process. With the classification created in this thesis, it is possible to look at the different possible influence mechanisms. However, the link from inputs to outputs is not so clear. For example, which should be the possible outputs from investment instruments? Section 7 provides some insight on the issue.

Finally, the classification created here and the detailed description of the innovation process should provide enough understanding of the possible choices for the firm for empirical estimation. Further chapters in this thesis take both of these concepts into account and estimate possible relationships between innovation policy instruments and firm innovation strategies.

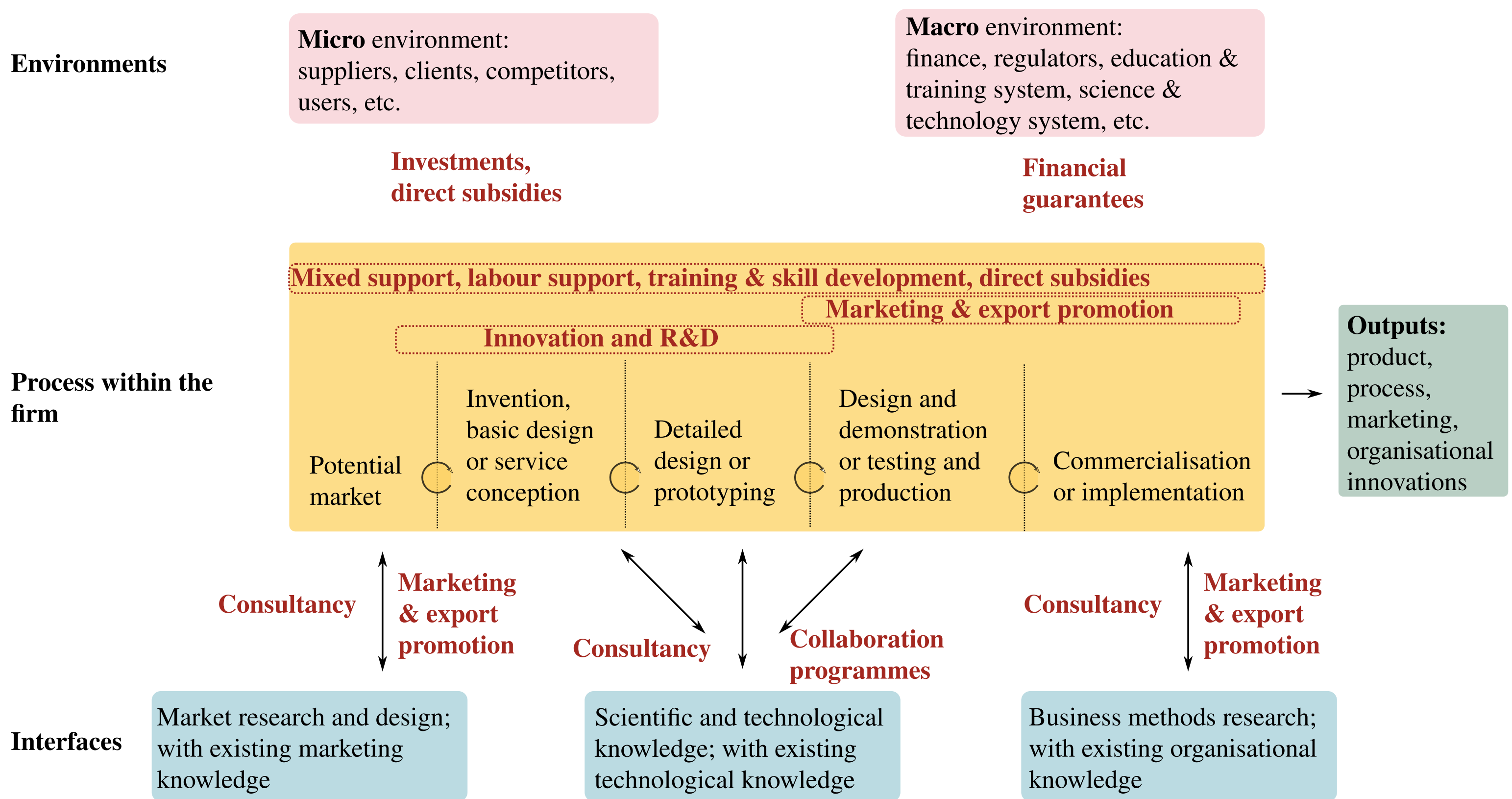

Figure 3.4: Possible effects of innovation policy instruments as inputs to the innovation process. Source: Caraça et al. (2009) with Author's modifications.

4. DATA

The data used in this dissertation is gathered from various sources for an in-depth analysis of the complex relationship between innovativeness, business activities and public support. Data about innovative activities comes from the Community Innovation Survey (CIS), data about public support from several public agencies and public registries, data about firm appropriation tactics from the Patent Office, and data about firm fiscal statement from the Business Register. All datasets are matched by their respective firm specific ID. All datasets are discussed in turn; their caveats, complementarities and benefits. An overview of all datasets and their sources is shown in Table 4.1

Emprical observations in this dissertation cover Estonian firms between 2002 and 2012, both years inclusive. Altogether, 3502 firms are analysed in an unbalanced panel data setting. The core dataset about firm innovativeness has been gathered by Statistics Estonia and is representative of the population of Estonian firms.

Table 4.1: Overview of datasets and their sources used in this thesis

Information	Data	Period	Data source
Innovative activities, inputs and outputs, knowledge sources, etc.	Community Innovation Survey (CIS)	2002-2012 (5 surveys)	Statistics Estonia
Policy instrument support	full register	2003-2015	Enterprise Estonia
Policy instrument support	full register	2001-2013	Agricultural Registers and Information Board
Policy instrument support	full register	2004-2015	Structural Funds register
Policy instrument support	full register	2007-2016	State Aid Register
Intellectual property rights	full register	1993-2015	Estonian Patent Office
Annual report data for firms	Annual reports	1994-2014	Estonian Business Register

4.1. Community Innovation Survey

There are two widely used methods to investigate firm innovative behaviour that also include outputs, i.e. innovations themselves. The first method is to use patenting data, which is readily available from local or international patenting offices. As with everything, patenting data has strengths and weaknesses. An overview of the positive and negative arguments has been made by Smith (2005) and Kleinknecht and Reinders (2012).

Positively, patenting data has a rich history, dating back more than a century by now. Patents are usually granted for promising new technologies with commercial application, i.e. innovations. Patents also systematically document underlying technologies and include citations to other patents and scientific works which can be used in a bibliographic analysis.

The downsides of patenting data are related to what can actually be patented. Patents rely heavily on inventions. They can be without any commercial success or current application, meaning that they should not be considered innovations as such. Patents are widely used in some sectors but not used in others at all. For example, patenting activity in software based solutions is low, because the speed of progress is too fast to rely on patenting rights. Patents can also be used as a strategy to hinder the progress of the competition. In general, patents are not a sure indicator of progress and economic significance to any firm.

The second widely used data for investigating innovations is survey data. Subject and object approaches can be distinguished (Smith, 2005). The object approach identifies formidable innovations through some external mechanism and surveys firms about their innovative behaviour. The most famous example in the relevant literature is the SPRU database (Townsend, 1981). It covers approximately 4000 major innovations in the UK between 1945 and 1983. They used a panel of experts from various fields to identify innovations and surveyed information about sources of knowledge, types of innovation, links with other industries and so forth. This type of data collection is rare and not widely available. In addition, innovations must be somewhat significant in society for experts to name them worthy of inclusion, leaving out many incremental innovations (Smith, 2005). Results from this approach are still relevant, albeit the original method is difficult to replicate.

The subject approach relies on firm-level activity and details information about general innovation inputs and outputs, such as R&D, knowledge base, innovation types and financing (Smith, 2005). This is the survey type used in this thesis.

The CIS is arguably the most used survey about innovative activities in the world, at least in the EU. It is a standardised survey, coordinated by Eurostat and carried out by all Member States plus Norway and Iceland[1]. The CIS is part of the EU science and technology statistics designed to survey innovative activity in enterprises. All the questions are harmonised between Member States for com-

[1] Further information can be read from the Eurostat website https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey

parability, and relevant materials are published in the Oslo Manual (2005). Data from the CIS is also used as one part of the European Innovation Scoreboard.

The CIS surveys firms about relevant inputs and outputs of innovative activities. There have been 9 waves of the CIS in Europe so far. Over these waves, the survey has been modified to clarify definitions, while some topics have been added and others removed. In addition, there is a special section in every wave designed to investigate some aspect of the innovative process. Recent examples are the role of design in innovative activities and the role of different appropriation methods. The most relevant dimensions which are surveyed in the CIS are:

- Expenditure on activities related to innovation, e.g. acquisition of machinery, R&D, training & skills development, design, etc.
- Types of innovation, different output configurations, e.g. are these product or process innovations, new products or services, new to the local market or new to the world, marketing and organisational innovations
- Sources of knowledge, e.g. suppliers, clients, universities, etc.
- Collaboration partners, e.g. within the group, clients, suppliers, etc.
- Strategy in developing innovations, goals and barriers, e.g. cost reduction, market penetration, etc.
- Financial data, public support, size, firm position in a group, etc.

The CIS is not free of criticism. It is a self-reported survey, it does not survey non-innovative firms, and it is based on technological innovations.

Self-reported surveys rely on the respondent to answer truthfully without any aid from the researchers. Their cues are only what is written down on the questionnaire. Therefore, there can be bias in answers in self-reported surveys (Bertrand and Mullainathan, 2001). People are influenced by the way questions are formulated[2]. Even the order of answer lists might influence results. Furthermore, there is social desirability bias, whereby people have a tendency to answer in a way they believe the researchers or the wider audience would like them to, which serves a desire to fit in. Lastly, self-reported surveys may lack coherency from the same respondents. The measured outcome of some surveyed attitude can be relatively unstable in a short period.

The CIS does not survey firms which have not innovated very well. Firms that respond that they have not had any innovations or cancelled projects on innovations can skip most of the survey. The CIS is designed in a way that all questions

[2] A whole range of studies have been devoted to this in the behavioural economics field, see also Kahneman (2011) and Thaler and Sunstein (2009)

are in the context of innovative activities. For example, the question about cooperation with possible partners is phrased like this: ”did your enterprise co-operate on any of your innovation activities with other enterprises or institutions?” This means that we are missing a counterfactual in the survey. Firms that cooperate with partners, while believing that they do so in a context that is not innovative, are missing from our responses. Therefore, we can investigate whether firms that believe themselves to be innovative are cooperating with partners, but we can not investigate whether firms that are cooperating with partners are innovative. One solution to this problem is to add external data from other sources which reliably covers the sample. Then we can also investigate whether some type of activities also correlate with firms who believe themselves to be innovative. The reverse condition is always true. If we observe that innovative firms never cooperate, we can argue that innovative firms are not correlated with cooperation. However, such conditions are rare to exist.

The CIS relies on a definition of innovations which is more technology based (Smith, 2005). Since the CIS is also evolving, the definitions have laxed a bit over different waves. Smith (2005) brings forth an example from the second CIS carried out in 1996[3]. The definition of innovations is following: “*Technological innovations comprise implemented technologically new products and processes and significant technological improvements in products and processes*”. Furthermore, new products and improvements are also described in a manner which emphasises technological upgrade.

Since then, CIS 3 already made changes that can include less technology heavy innovations and it has continued since. In this thesis, CIS 4 (2002-2004) until CIS2012 (2010-2012) is used. Therefore, examples are brought from those. In CIS 4, the general definition of innovations is following: “*A product innovation is the market introduction of a new good or service or a significantly improved good or service with respect to its capabilities, such as improved software, user friendliness, components or sub-systems*” (Eurostat, 2004, p. 4). It is self-evident that the CIS has reduced its technology heavy definition over time to include a somewhat more vague definition of innovations. The Oslo Manual (2005) justifies that this definition tries to encompass all sorts of innovations, whether they are clearly defined projects with a single significant change or a series of small incremental changes. In the latest CIS used in this thesis, CIS2012 , the definition used is following: “*A product innovation is the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems*” (Eurostat, 2012). These are rather similar and comparable.

[3] Unfortunately, I am unable to find a copy of the original CIS 2. Estonian CIS waves start from CIS 3.

The CIS surveys firms fully if they have done or continue doing product and process innovations. Organisational and marketing innovations are also surveyed, but most of the questionnaire can be skipped for them. This also contributes to the counterfactual problem. The definitions of organisational and marketing innovations have become wider between 2002 and 2012.

Organisational innovation is defined in CIS 4 as "*the implementation of new or significant changes in firm structure or management methods that are intended to improve your firm's use of knowledge, the quality of your goods and services, or the efficiency of work flows*" (Eurostat, 2004, p. 10) and in CIS2012 as "*a new organisational method in your enterprise's business practices (including knowledge management), workplace organisation or external relations that has not been previously used by your enterprise*" (Eurostat, 2012, p. 9). The first is defined in terms used mostly by economists who study innovations and the latter in terms used in business and referring to managerial decisions. This could have contributed to the cognitive bias problem. Respondents read fairly similar text in meaning, but the wording has changed notably. There is no way to tell how much it has contributed to the noise in responses.

Marketing innovations have undergone similar changes. In CIS 4 they are defined: "*A marketing innovation is the implementation of new or significantly improved designs or sales methods to increase the appeal of your goods and services or to enter new markets*" (Eurostat, 2004, p. 10). In CIS2012: "*A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from your enterprise's existing marketing methods and which has not been used before*" and they must involve significant changes to the four P's[4] and exclude seasonal or routine changes (Eurostat, 2012, p. 10). The latter definition is a bit wider, including more types of innovation as possible answers.

Some other questions in the survey have also undergone minor changes during this period. For example, cooperation with clients in general was surveyed in the earlier waves, whereas public and private clients are separated in latter CIS waves . All similar examples are combined into one or matched to give continuous and comparable answers. If some questions are completely dropped or have undergone too vast changes, these are not included in any analysis. Unfortunately, this also meant that many interesting questions had to be excluded.

An example from CIS2012 on how questions related to innovative activities are formulated follows. About sources of information: "*During the three years 2010 to 2012, how important to your enterprise's innovation activities were each of the following information sources? Include information sources that provided information for new innovation projects or contributed to the completion of existing projects,*" and a list of potential sources and their relevance follows (Eurostat,

[4] Product design or packaging, placement, promotion or pricing

2012, p. 8). These details are relevant about our conclusions. Firms are surveyed only about sources of information related to innovative activities and about possible projects that they reported earlier — product and process innovations. Therefore, the CIS surveys about possible management choices while delivering innovations, but not for regular business activities, if these two do not coincide.

Finally, a note on CIS measures of innovation. Firms are surveyed whether they have done any innovations in a three year period. They may choose several types of innovation, e.g. new products, services and distribution processes. However, the answers are binary and without weights. It is not possible to infer which of these innovations were more important. Furthermore, it is not possible to infer how many innovations were made in total. Many firms have several product lines and several services where they can commercialise innovations simultaneously.

There is one question regarding the importance of innovations in the CIS. Firms are asked what percentage of their turnover is due to these recent innovations. This is known as innovation intensity in relevant literature. According to the Schumpeterian view of innovations, a higher share of innovative products leads to competitive advantages and better performance. However, relevant questions only survey product innovations and do not disentangle these. Therefore, if a firm does not produce a new product or service innovation, we cannot gauge the importance of innovations in relation to firm turnover or profitability with CIS data.

4.2. Public sector support data

Data about direct business support instruments comes from all relevant public agencies on the local and national level in Estonia between 2001 and 2016. Four datasets have been merged to gather population data in Estonia. These will be introduced in turn.

Two public agencies, Enterprise Estonia and Agricultural Registers and Information Board are main paying agencies who deal with both large firms and SMEs. Both have supplied their full register of all business support given to beneficiaries, including project titles, relevant instruments, sum of money and dates (Agricultural Registers and Information Board, 2016; Enterprise Estonia, 2015).

Enterprise Estonia was founded in 2000 as a successor to five different governmental foundations merged during a reform. These five foundations were part of different ministries at the time, in charge of tourism, regional, trade, innovation, infrastructure and transit policy instruments. Enterprise Estonia became one central agency in charge of all these policy instruments for an overarching Estonian entrepreneurship and regional policy governance.

The Agricultural Registers and Information Board (ARIB) was also founded in 2000. The ARIB was a successor to a foundation created in 1998 that was in charge of the EU SAPARD[5] programme after Estonia initiated EU accession talks. The ARIB has been under the Ministry of Rural Affairs (previously Ministry of Agriculture) since its inception and is the relevant paying agency for Estonia's rural development policy instruments. However, rural development policies have included a wide range of instruments geared towards agricultural and non-agricultural firms to increase their productivity and innovativeness. Mostly, they are funded by the Common Agricultural Policy (CAP). Relevant funds are the European Agricultural Guarantee Fund (EAGF), the European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF).[6]

Estonia joined the EU in 2004. Many public sector support instruments were created under the auspices of EU Structural and Investment Funds (ESIF). There are three types of funds which are highly influential for Estonian instrument funding (State Shared Service Centre of Estonia, 2018):

- The European Regional Development Fund (ERDF), which offers support to the Member States in order to harmonise the development of various regions and strengthen economic and social cohesion in the European Union.
- The European Social Fund (ESF), which supports initiatives that promote employment, contribute to the improvement of people's qualifications, and increase the competitiveness of employees.
- The Cohesion Fund (CF), which supports those Member States where the gross national product is below 90% of the European Union average. The CF provides support for large environmental and infrastructure projects. Estonia is among the Members States that receive this support.

These funds are main contributors to Estonian policy instrument funding in nearly all categories. Varblane (2014) suggests that about 75% of investments by the public sector and 90%-95% of entrepreneurship support instruments in Estonia are funded via funds related to the EU. Therefore, the EU Structural Funds register is also combined in our dataset. These include many of the larger projects, some infrastructure projects and instruments geared towards other organisations, such as workshop or training providers. This register is publicly available since 2004 (State Shared Service Centre of Estonia, 2015).

[5] The Special Accession Programme for Agricultural and Rural Development started 6 months after EU accession negotiations began.

[6] These are current funds. The CAP was founded in 1962 and has a rich history with many reforms. These funds were replacements to the original European Agricultural Guidance and Guarantee Fund (EAGGF) set up in 1962.

In addition, Estonia's State Aid register has been culled. In 2007, Estonia transposed EU competition regulations into Estonian law and set up a digital State Aid register (Ministry of Finance, 2016). All Estonian state aid and *de minimis* aid is tracked through this register. EU competition policy has strict state aid rules, so exemptions have to be notified and are monitored. All aid must be approved by the European Commission, fall under block exemptions or be under *de minimis* aid limits. The maximum amount of *de minimis* aid currently allowed is 200 000 EUR per undertaking over any period of 3 fiscal years.

Since many direct business support instruments are low in sum, a balance of payments is kept for every beneficiary in the register. Also, there are examples in this register where aid given to firms is indirect, calculated afterwards. For example, when workers have been retrained in a public program, the cost of the program is not payed directly to the firm, but it has been estimated and kept on balance in the firm's state aid or *de minimis* aid total sum. This is one, and probably the best, way to observe the treatment of instruments where funds have not been paid directly to the firm.

The Structural Funds register and State Aid register add another 20 public organisations who have been giving direct business support over the years. The main paying agencies are the Environmental Investment Centre, Technical Regulation Authority, Ministry of Economic Affairs (only very large projects directly), Ministry of Finance (also large projects), Estonian Unemployment Insurance Fund and some specific foundations for R&D support and loan guarantee services for SMEs. A full list of paying agencies and instruments is given with descriptive statistics in Chapter 5.

This data covers direct support given to businesses, non-profit organisations and public enterprises. Instruments specially meant for public organisations, for example local governments, are not included.

Most of these instruments provide direct support for which firms have to apply themselves. Many instruments operate within specific sectors, limit access to firms according to size or age, and specify conditions for eligibility criteria.

4.3. Patent office data

Data about the different strategies firms have adopted to appropriate their innovations has been provided by the Estonian Patent Office (The Estonian Patent Office, 2015). Data covers years between 1993 and 2015. The Estonian Patent Office has acceded the European Patent Convention in 2002, after which they also provide access to all patents enforced in Estonia by others.

The Estonian Patent Office provided data about all trademarks, industrial designs, patents, utility models and geographical indications that have been granted to Estonian firms. These are all types of intellectual property rights that can be applied for in Estonia. The following brief descriptions are based on information on the Estonian Patent Office website (The Estonian Patent Office, 2018).

Trademarks are graphically represented signs which can distinguish goods and services from competitors' goods and services. Trademarks are cues for consumers that identify specific goods or services. Main types are i) word marks, words or letters; ii) combined marks, words and letters with figurative elements, colloquially known as logos; iii) figurative marks, only figurative elements; iv) three-dimensional marks, three-dimensional representation of product, packaging, etc; v) sound marks, sounds or melodies.

Trademarks are only used to distinguish goods. They do not offer legal protection about the production process or contents of any good. Trademarks in the Estonian trademark register only offer protection within Estonia, so firms that only export might choose not to protect their trademarks in Estonia. However, the cost of entering a trademark in the Estonian trademark register is currently 45 euros. Arguably, cost is not prohibiting any firms from protecting their brands, logos or slogans.

Trademarks are not obligatory for firms. They provide a right for the firm to use specific words, letters or pictures when designing and commercialising their products. Innovative firms that are concerned with protecting their unique products or services in the local market should protect not only the production process but also the commercial product design.

Industrial design is a two or three-dimensional appearance of a product, i.e. the outer shape or the appearance of a product can be registered as an industrial design. Similarly, the exterior design of a product can be registered. This can be a cloth pattern, website design, furniture design, shoes with specific patterns, and so forth. Only the exterior design is protected, the part that is visible to consumers. Hence, technical solutions or production processes, or even parts of the product that are not visible, can not be protected with industrial designs.

Industrial designs give manufacturers exclusive rights to produce products with distinctive visual appearances. These rights can be sold or licensed to others. A real life example follows. A new venture designed an outdoor grill kitchen as one of its first products. Another Estonian outdoor grill manufacturer scoured the web for inspiration and decided to copy the first venture's design and presented it at a trade-fair. Since the new venture sought protection for its design, the two firms reached a consensus that the other firm would stop producing a very similar product.[7] However, necessary changes to the initial product for it to fall out of protection can be small enough that designers would be worried. Still, current state fees for industrial designs are around 100 euros, which would not be considered restrictive.

Patents and utility models are intellectual property rights for inventions which are technical solutions to technical problems. These can be devices, processes, materials or combinations thereof. Patents are used for inventions with a new inventive step and are used for industrial applications. Utility models have more relaxed requirements for the inventive step. Patents can form a group of linked inventions, whereas utility models are all distinct.

Patents are considered to be very indicative of innovations, so firms wish to protect their new technological solutions and establish short-term monopoly rights. Patents are regularly used as a proxy for innovations. However, some shortcomings are discussed in chapter 4.1. For further discussion on the use of patents as innovation indicators, see Smith (2005) and Kleinknecht and Reinders (2012). In this thesis, patents and other appropriation are indicators of innovation strategies. Since there are differences in appropriation methods between industries, use of intellectual property rights is one distinguishing character to differentiate managerial choices.

Geographical indications are used to indicate specific geographical origins of a product and, often, specific terms associated with products from that geographical region. Worldwide known examples are brandies from the Cognac region called Cognacs or hard cheeses called Parmigiano-Reggiano or Parmesan, which can be produced in five specific Italian provinces. Other manufacturers are prohibited from using the same terms on their products.

After Estonia's accession to EU, these geographical indications which are protected on the EU level are no longer under national law. Some firms have pursued geographical indications in Estonia to protect their products from being copied. Geographical indicators have incentives which influence local producers to innovate on the marketing and production side (Moerland, 2018).

The role of intellectual property rights data in the context of this thesis is to indicate innovation strategies. Main innovation outputs are acquired from the CIS data. Arguably, CIS data is more rich than data from patent offices. Especially for industries where patenting or other types of intellectual property rights are not very common. Estonian firms are not very R&D heavy or inventive in general, and the CIS should give a better understanding of their innovative behaviour. Descriptive statistics about Estonian firms' use of intellectual property protection is given in Chapter 5.

[7] https://www.aripaev.ee/uudised/2015/05/30/disainerid-hadas-kopeerijatega-ulaelu-kook-patent

4.4. Business Register data

The Estonian Business Register holds data about firms, foundations and state entities. They cover general information, personnel information and annual reports. In this thesis, data about firms' annual reports between 1994 and 2014 has been provided by the Estonian Business Register privately (Centre of Registers and Information Systems, 2015).

Annual report data contains information about firm balance sheet, income statement, cash flow statement and statement of changes of equity. There is also some general information available, such as the number of workers and industry NACE code. However, since annual report data allows firms to make their own structure of account names, these are often not easily comparable. This means that some assets and liabilities are combined under different headings or divided in a structure which makes sense only for that specific company. Similarly, Estonian regulations allow for two different schemes to present income statements which cannot be combined together.

Due to these reasons, many interesting qualities of firms have to be left out of the final combined dataset, because there would be too few comparable observations left. However, there are some very general accounts which are of interest. For example, firms with machinery have to keep it on balance and deduct amortisation. This can give a general idea about the reliance on capital goods within a firm. Similarly, the Business Register is the only dataset which contains firm founding date reliably.

4.5. Combined dataset

Data from previously described organisations has been merged based on business identity numbers. Since CIS microdata is confidential and a representative sample of the population, all other datasets must be about exactly the same sample or whole population. Due to these reasons, all other datasets used are about the whole Estonian firm population and have been merged with CIS data. Briefly, all of the following datasets used in this thesis have been combined into one:

- CIS4 (2002-2004) (Eurostat, 2004)
- CIS2006 (2004-2006) (Eurostat, 2006)
- CIS2008 (2006-2008) (Eurostat, 2008)
- CIS2010 (2008-2010) (Eurostat, 2010)
- CIS2012 (2010-2012) (Eurostat, 2012)

- Enterprise Estonia (2003-2015), public sector support data (Enterprise Estonia, 2015)
- Agricultural Registers and Information Board (2001-2013), public sector support data (Agricultural Registers and Information Board, 2016)
- Structural Funds (2004-2015), public sector support data (State Shared Service Centre of Estonia, 2015)
- State Aid register (2007-2016), public sector support data (Ministry of Finance, 2016)
- Estonian Patent Office (1993-2015), intellectual property rights data (The Estonian Patent Office, 2015)
- Estonian Business Register (1994-2014), annual report data (Centre of Registers and Information Systems, 2015)

Statistics Estonia conducted CIS3, which spans between 1998 and 2000 (Eurostat, 1998). However, CIS3 has been omitted from this analysis due to three reasons. Firstly, CIS3 also included firms with less than 10 employees. This has never been done again. Therefore, the sample in CIS3 is a bit different than in following CIS waves. Secondly, there is a gap between CIS3 and CIS4. This creates an even bigger unbalance in the panel dataset. Often we aim to calculate the percentage of change from one stage to the next between two periods. We have no information about the period between CIS3 and CIS4. Thirdly, the definitions of innovation between CIS3 and CIS4 are different. CIS3 relies more heavily on technological innovations, asking firms to consider innovations that are founded on technological developments. CIS4 and subsequent waves are more alike in their definitions and are therefore more comparable.

As is apparent, some datasets have gaps in their overlaps. This is because some registers were founded in a latter date. Some registers were founded because these funds became available at that time. Public sector support to private firms really took off after 2007, when Estonia was fully part of the EU programme period of 2007-2013. Before 2004, there were only brief and fairly small instruments. However, the data about periods until 2004 is scarce to come by. Most agencies in charge of instruments did not use fully digital application systems until later dates. Therefore, data quality and completeness can be a problem around that time.

The combined dataset is based on CIS observations between 2002 and 2012. This covers five waves of CIS. All other datasets have been merged with CIS data, in belief that external datasets are full Estonian population datasets without missing values. This combined dataset has 9155 observations. It is an unbalanced panel dataset. Data descriptives are in Chapter 5.

For ease of reading, a separate bibliography item refers to this combined dataset (Innovation Data, 2018).

A final note before presenting descriptive data: since the CIS is the basis for national data about innovative activities, it is a representative survey in regards to firm size for firms with more than 10 employees. It is also representative of sectors which it covers. To achieve this, Statistics Estonia uses survey weights to obtain estimates of population parameters. However, these survey weights are not designed to be representative for innovative strategies or the use of public sector support. For these reasons, data presented in this thesis from the CIS survey is unweighted. This also means that data and results presented here should be indicative for the firms in the sample used.

The difference in results between weighted and unweighted data is not large. For example, the share of innovative firms in Estonia differs by an average of 6.4% in the CIS waves covered between the unweighted and weighted sample. The unweighted sample has a higher share of innovative firms in every wave. On average, the survey weights used for population estimates weight non-innovative firms higher than innovative firms. However, since the main objective here is not to analyse the macro estimates of Estonian firms, it is possible to proceed without weighting the sample.

5. OVERVIEW OF THE ESTONIAN CASE

5.1. Estonian business environment, 2000 - 2015

In this section, I will give a brief overview about the conditions in which Estonian firms have been during the period of interest. When available, data is shown for the years between 2000 and 2015, three years before and after the survey data used in estimations. The macro context is relevant for understanding the rather turbulent period Estonian firms have experienced for the past 20 years.

Estonia is a small open economy with a bit more than one million people. As a former Soviet state, it was regarded as a transition economy in the 1990s. The period of interest in this thesis corresponds to a different type of transition - accession to the EU, changes in regulations and access to the EU open market. EU funds were gradually available to Estonia several years before the official accession date. Preparations for accession started in 1999.

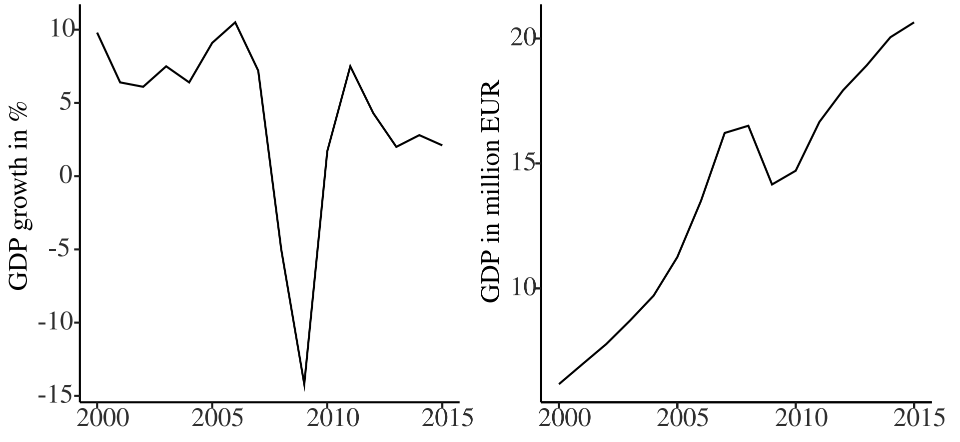

Figure 5.1: Estonian GDP.
Left: GDP chain-linked volume, change compared with same period of previous year, percentages (seasonally and working day adjusted).
Right: GDP at current prices, in million euros (seasonally and working day adjusted).
Source: Statistics Estonia (2019e)

Between 2000 and 2015, Estonia's GDP has grown more than threefold, as shown in Figure 5.1. GDP per capita has grown more than fourfold during this period, since the population has been in a slow decline. This has put pressure on firms to increase productivity without access to extra labour. Wages in Estonia have been smaller than in Western Europe during this period, and the pressure for migration within the EU for workers has been mostly outward.

At the same time, Estonian firms, with the help of foreign direct investments and EU funds, were transforming most industries to increase productivity. Figure 5.2 shows productivity per employee growth and nominal positions between 2000 and 2015. Overall, there is large growth visible in nominal position, as productivity per employee is about three times higher in 2015 than 2000. However, there is also a slowing trend visible in growth percentages. In general, during the period of interest in this thesis, there has been a large growth in productivity per employees, driven largely by investments in fixed capital.

Figure 5.3 shows the main categories of investments in fixed assets. Intangible assets are also included in the other fixed assets category. The main investments are related to investments goods, such as machinery, equipment and construction. Estonian firms have been investing in fixed assets to close the gap with other European firms with more modern technology. For comparison, firms were investing more than one billion euros in fixed assets in year 2000 in Estonia. At the same time, intramural and extramural investments in R&D for all Estonian firms totalled 11 million euros (Statistics Estonia, 2019i). Similarly with other investments, R&D expenditure also increased to around 140 million euros in 2015 (Statistics Estonia, 2019h). Productivity increase in Estonian firms has been driven mainly by fixed assets, new machinery, new equipment and other investment goods. Until 2015 at least, R&D expenditure has played a minuscule role.

For large economies, the question can become whether firm innovation affects business cycles (Jovanovic and Lach, 1997), or, even broader, whether new technologies with enough diffusion and productivity increase can create long positive business cycles (Freeman and Perez, 1988). For small open economies, it is fairly clear that firm behaviour is driven by outside influence. Similarly, on a micro level, firm behaviour is influenced by its environment. How much business cycles affect innovation strategies is not certain. There is some evidence that business cycles affect performance in innovating firms less than in non-innovating firms (Geroski and Machin, 1993). It is also evident that business cycles affect investments, but how much they affect other elements in innovation strategies, such as cooperation, firm-specific capabilities or innovation culture, will be investigated in this thesis.

The main contributors to Estonian GDP are manufacturing, trade and logistics sector and real estate activities. Figure 5.4 shows the share of total value added for different economic activities. Between 2000 and 2015, there is a slow upward

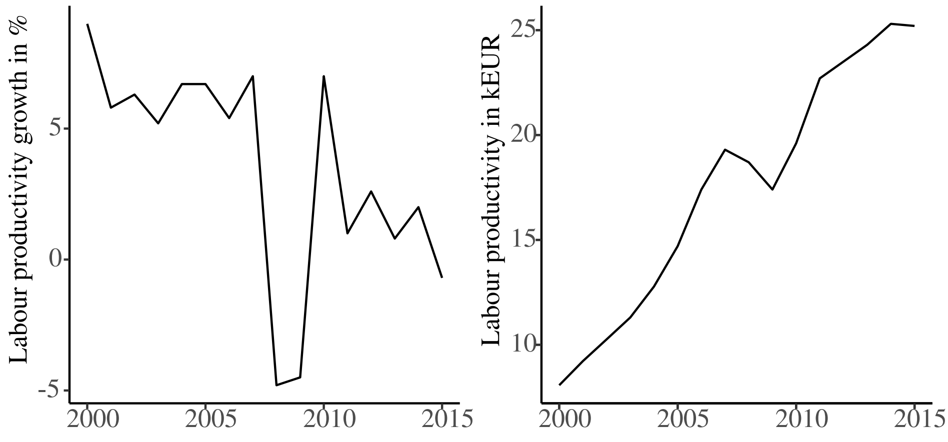

Figure 5.2: Estonian firm productivity.
Left: Productivity per employee. Real indicator change compared with same period of previous year (seasonally and working-day adjusted), percentages.
Right: Labour productivity per person employed on the basis of value added, in thousand euros.
Source: Statistics Estonia (2019a,c,g)

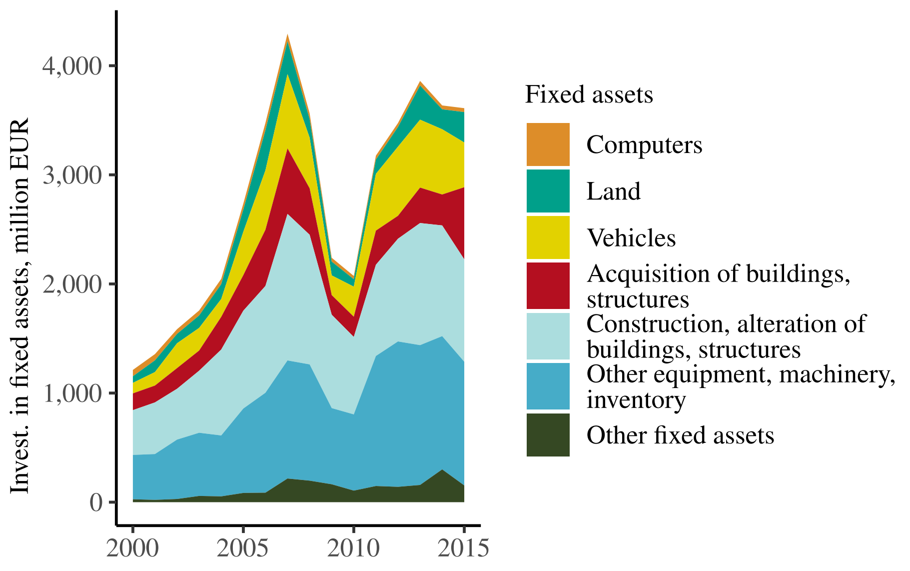

Figure 5.3: Investments in fixed assets, in million euros. All firms; public sector and finance sector omitted.
Source: Statistics Estonia (2019b,d)

slope for scientific and technical activities, which consists of firms whose main activity is R&D. For other activities, cyclical behaviour with recovery can be seen.

Large structural shifts between 2000 and 2015 are not visible. The economic activities which contributed the most to Estonian GDP in 2000 have relatively similar shares and ranking in 2015.

5.2. Innovative activities, 2002 - 2012

Descriptive statistics about innovative activities in Estonia are directly taken from the CIS, unweighted, and other datasets combined. All are described in Chapter 4. The CIS covers three years, for example from 2002 to 2004, inclusive. The data presented from the CIS has overlapping years between every wave. The firms covered are referred to as the CIS sample, even though they are the basis for population estimates and national statistics. The reasoning for this can be found at the end of Chapter 4.1.

The five CIS waves used cover 10 years. Altogether there are 9155 observations from 3502 firms. This means that the data used in this thesis is an unbalanced panel dataset. Table 5.1 highlights the number of respondents in different CIS waves. Note that in Estonia, there were about 7500 firms on average with 10 or more employees during this period (Statistics Estonia, 2019c). The CIS surveys roughly 46% of the whole Estonian population of firms with 10 or more employees.

Table 5.1: Number of CIS respondents by wave

CIS wave	Number of respondents	Firms with technological innovative activity
2002 - 2004	1747	903
2004 - 2006	1924	1068
2006 - 2008	2026	1134
2008 - 2010	1735	936
2010 - 2012	1723	770
Total obs.	9155	4811
Total firms	3502	2277

Source: Innovation Data (2018)

Firms demonstrating 'some' innovative activity means that they answered positively to at least one of three questions. They had either: (a) new product innovations (goods or services); (b) new process innovations; or (c) ongoing or abandoned innovation activities for process and product innovations. This is an important caveat in the CIS. If the respondent answered no to all of these questions, they would skip several questions about their activities. Firms that did, for example, marketing or organisational innovations, could skip questions regarding cooperation partners, knowledge sources and so forth. Therefore, in all descriptive statistics and in statistical modelling, there is data available from the CIS about firms that had some technological innovative activities. Descriptive statistics where n = 4811 applies to observations where firms had some innovative activities and there is information. Descriptions where n = 9155 applies to all observations in the CIS. This does not apply to all external data — it has been matched for all firms — thus n = 9155 always and counterfactuals for innovative activities also exist.

Another note on the difference between national innovation statistics and the data presented here. Usually when population data about firms that had innovations is presented in national statistics, it only refers to categories (a) and (b) in the previous paragraph, i.e. firms that had technological innovations. In this thesis, for continuity and brevity, firms with ongoing or abandoned innovative activities are also included in the group of innovative firms. This is done for two reasons. Separating these groups in different steps is difficult to follow, such as by using one definition for descriptive statistics and another for statistical modelling. Secondly, in this thesis I analyse innovation strategies. Firms with ongoing innovative activities or those that abandoned them for some reason also contribute to our knowledge of innovation strategies. The fact, that they have not reached their outputs, e.g. new products or services, does not mean their innovation strategies are not similar to other firms. Therefore, they should be included in the models as well.

Since this is an unbalanced panel, a brief description on how many observations can be used to estimate dynamics. In the most simple case, we need only two observations from a single firm to estimate dynamics, and it would be best if these are two consecutive observations. Since the CIS is an anonymous survey which aims to be representative of the whole population and, as it turns out, it covers a rather large percentage of the population, there are smaller subpopulations in the data where we can observe dynamics.

Table 5.2: Number of firms, grouped by observations per firm

Observations per firm	Number of firms	Cumulative share of all observations
5	654	35.7%
4	418	54.0%
3	546	71.9%
2	691	87.0%
1	1193	100.0%

Source: Innovation Data (2018)

From Table 5.2, we can observe that there are 654 firms for which we have 5 observations in the data. This means full coverage between 2002 and 2012. In observation terms, these firms constitute 3270 observations, around 36% of the dataset. More than half of the dataset consists of firms which have been surveyed at least four times. This does not mean that all observations have been consecutive. There are gaps present for many firms.

Appendix II shows the most prominent panel data patterns. It is evident that we can observe consecutive periods for most of the firms in the dataset. Around 27% of all firms in the dataset have four or more consecutive observations recorded. Around 43% of firms in the dataset have three or more consecutive observations recorded. This means that for most firms, we can observe rather short periods of consecutive innovative activities.

Figures 5.5 and 5.6 both show firm innovativeness by categories. The former is based on two larger categories: technological and non-technological innovations. The latter show these categories when divided into subcategories: product, process, marketing and organisational innovations.

It is evident that innovative activities do not follow similar cyclic trends as investments. Firms in the CIS sample show a relatively modest downward trend in innovativeness in all categories. As far as I am aware, there has not been any research done to explain this downward trend. It does not correlate well with fixed asset investments nor with business cycles. When investigating firm innovation strategies for this period, it is expected to witness more non-innovating strategies appearing in later periods.

Figures 5.7 and 5.8 show innovative firms with expenditures on some type of innovative activities. Figure 5.7 shows the share of innovative firms engaged in particular innovative activities. For example, about 85% of all innovative firms in the period between 2002 and 2012 made some type of investments in machinery. Unfortunately, there is no information about firms which were not innovative at the time. The simple conclusion is that the innovative firms almost always had investments in machinery, but we can not infer whether if non-innovative firms were any different.

The other category here refers to activities which do not belong to any other category. The 2010 CIS proposes this example: ”Other activities to implement new or significantly improved products and processes such as feasibility studies, testing, routine software development, tooling up, industrial engineering, etc” (Eurostat, 2010). The other category seems to be the only one which has a relatively large drop in share of firms engaged between 2010 and 2012. The survey questions did not go through any significant changes during this time which could explain the drop.

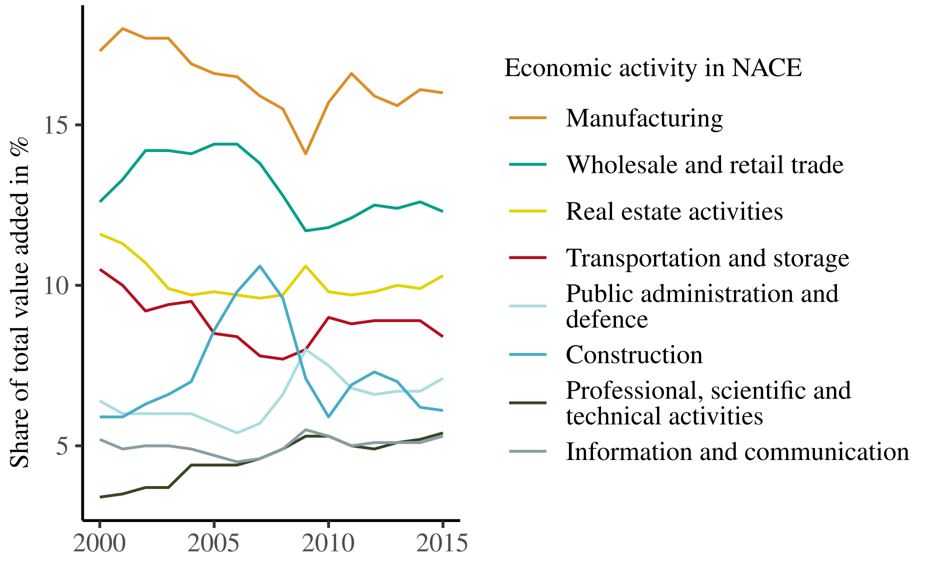

Figure 5.4: Share in economic total value added at current prices, percentages, by economic sectors in NACE. Sectors with share less than 5% in 2015 omitted.
Source: Statistics Estonia (2019f)

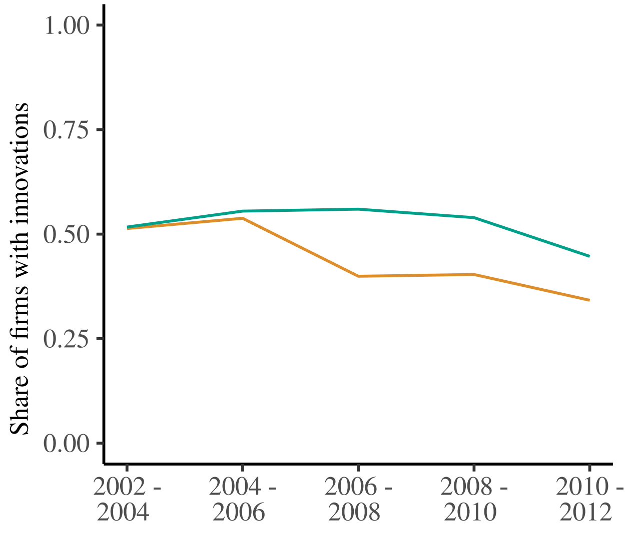

Figure 5.5: Firm innovativeness, technological and non-technological innovations. n = 9155.
Source: Innovation Data (2018)

The CIS investigates whether innovative firms had any of these types of innovative activities: in-house R&D; external R&D; acquisition of machinery, equipment or software; acquisition of external knowledge; training for innovative activities; market introduction of innovations; and other. CIS 2010 and CIS 2012 also surveyed whether firms had any design related innovative activities. However, since it is relatively new and can not be estimated for all observations, it has been omitted.

What can be observed is that the share of firms which engaged in these activities does not imply cyclical behaviour. There is a small increase in R&D related activities, both in-house and external R&D. Also, there is a moderate increase in knowledge acquisition activities. It seems that the share of firms engaged in machinery and software acquisition has a relatively small downward trend, and firms engaged in R&D related activities show a relatively small positive trend.

Figure 5.8 depicts expenditure on these innovative activities. However, the categories in the CIS are more narrow than the question related to engagement. Expenditure sums are related to a more technological understanding of innovation without training, marketing, design and other activities.

The total sum of innovation expenditures for the CIS sample looks fairly similar to the whole Estonian population investments in fixed assets, depicted in Figure 5.3. What is relevant is that only investments in machinery and other equipment show a cyclical trend. Two major events happened at the same time as when this drop occurred. Firstly, it was the global economic recession, now known as the Great Recession. Secondly, 2007 was the end of the EU programming period 2004-2006 (from the Estonian accession perspective), and the start of the EU programming period 2007-2013. This means that many instruments for public support also ended, and it took some time for new ones to begin. In the latter part of this chapter, descriptive statistics about public support is also shown for comparison. The argument is that many firms could not rely on EU funded instruments for investments in machinery.

The second very important aspect from Figure 5.8 is the moderate positive trend of in-house R&D expenditures. It is not affected by business cycles. This implies that there may be a structural shift in how innovative activities were conducted between 2002 and 2012. At the beginning of the period, in-house R&D made up about 21% of all innovation expenditures. In 2012, it was around 38%. Expenditures on external R&D and knowledge acquisition have remained relatively stable during this period.

When Figures 5.7 and 5.8 are contrasted, two trends are apparent. There is a higher share of firms engaged in R&D activities, in-house or external, albeit the share is not higher by multiples. Secondly, these firms spend much more on in-house R&D than they did before. The only thing we can not infer from these graphs is whether they are the same firms that engaged in R&D.

Figures 5.9 and 5.10 show firms use and the importance of information sources while engaged in innovative activities. The sources of information are divided into four groups: market sources, internal sources, research and education, and other sources. Market sources are suppliers, clients, consultants and competitors. Internal sources are within the enterprise or within the group. Research and education sources are universities or other higher education institutions and public or private research institutes. Other sources are conferences, trade fairs, exhibitions, scientific journals and other publications, professional and industry associations. In Figure 5.9, the firm is considered to use any of the groups of information sources when at least one of the subcategories has been used. This means that most firms probably do not use all the information sources in a category simultaneously.

Almost all firms rely on some sort of information from market sources. The most popular categories in this group are suppliers and clients. Less frequent categories are competitors and consultants. Similarly, the other category is widely used by firms in the CIS sample. The most popular is conferences, used by about 75% of innovative firms. Journals and other publications are used by about half of the firms. Also, internal resources within the firm or within the group are commonly used as an information source.

Universities and public research institutes are used much less frequently as other information sources. They both have a small positive trend since CIS 2006, but there is a wide gap between these information sources and others. This small positive trend coincides with Figure 5.8, where a small continous increase in R&D budget can be seen.

There seems to be no cyclical behaviour in the use of information sources, which is a major decision of management when forming the innovation strategy. The macro trends indicate that these are not changed very often by firms. However, this can be confirmed by micro-level analysis later in the thesis.

Figure 5.10 indicates the mean importance of these information sources as given by the firms that used them. The mean of the group has been calculated as the mean of all observations within the group without any weighting. This means that the sources of information which were used more often are also represented more in the mean calculation within group. Firms had a choice to rate the importance of information sources as (1) low, (2) medium or (3) high importance.

Internal sources within the firm or within the group are considered to be the most important sources of information while engaged in innovative activities. Firms rely most on their own knowledge resources. The second most important group is market sources. Within this group, suppliers are more important than clients,

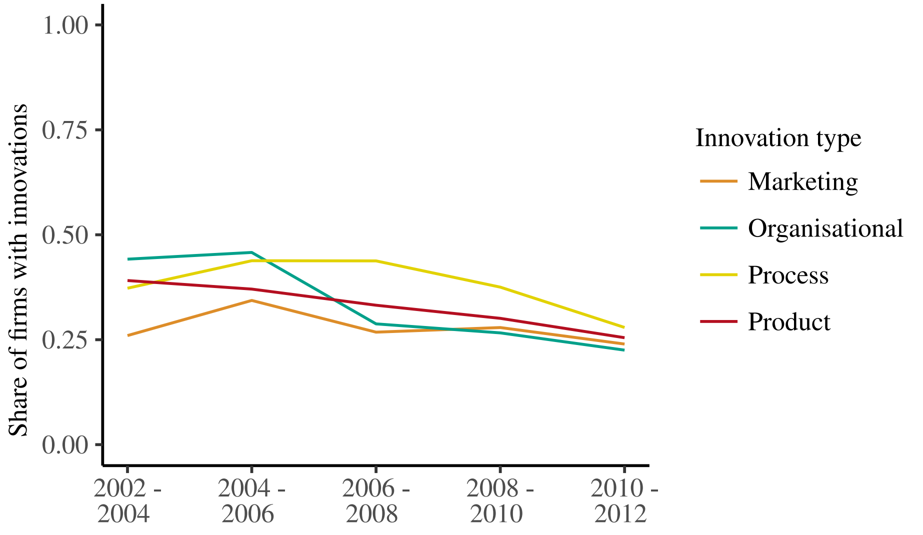

Figure 5.6: Firm innovativeness, by innovation type. n = 9155.
Source: Innovation Data (2018)

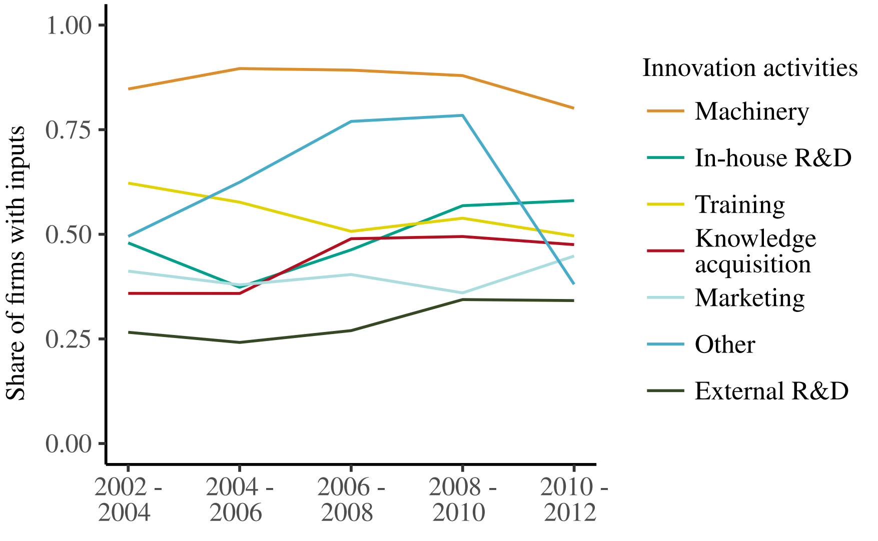

Figure 5.7: Share of innovative firms engaged in innovation activities. n = 4811.
Source: Innovation Data (2018)

followed by competitors and consultants. Firms in the CIS sample on the whole regard suppliers as their second most important source of information. The third most important category is clients.

There is a small difference in the order of use and importance of sources of information. Some sources are much more expensive than others. For example, extracting usable information from research institutes is more expensive and labour intensive than visiting a conference or reading a publication. Universities are used as a source of information less frequently than, for example, consultants and publications in the CIS sample. However, the importance of universities as a source of information, on average, is higher than both consultants and publications.

On the whole, Figure 5.10 raises the question of why the firms in the CIS sample do not consider their sources of information very important. There seems to be a small failure in the relationship. Firms do not consider the information they receive to be very important to their innovation process. This is one specific question that cannot be answered here but should merit an investigation in the future. There may be a short-coming in the experiences of both partners in Estonia, where learning-by-doing effects have so far not been enough. Unfortunately, there are not any visible positive trends on Figure 5.10 that would indicate a change in the near-term.

Figure 5.11 shows the share of firms that cooperated on innovative activities with partners by partner type. The contrast with information sources is obvious. Firms use many of these partners as information sources, but they do not engage in cooperation activities.

The most popular partners are similar to information sources. These are suppliers, internal, clients and the competition. However, there is no large difference between cooperation partner types. Universities are partners less often than, for example, clients, but the difference is much smaller when compared to information sources.

The lowest level of public and private research organisations as partners in Estonia can be explained by the lack of such organisations. There are not many possible partners in Estonia in this category.

Similarly to other possible choices in the business innovation strategy, the choice of partners on the macro levels seems to not be influenced much by business cycles. The share of firms with cooperation partners are relatively stable on the whole. For reference, the cooperation levels for Estonian firms are at the end of the first quartile when rankings are compared with other EU Member States (Eurostat, 2019).

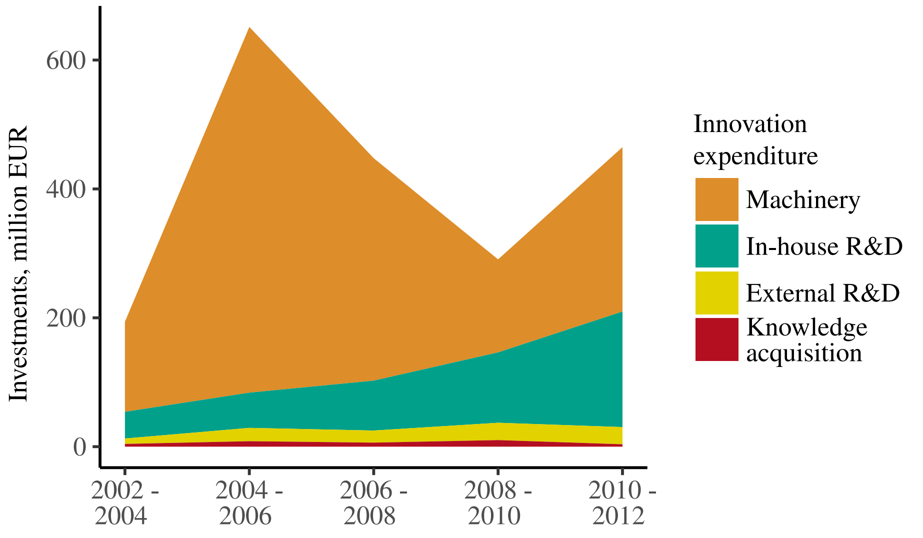

Figure 5.8: Innovation expenditures, by category, in million euros. n = 4811.
Source: Innovation Data (2018)

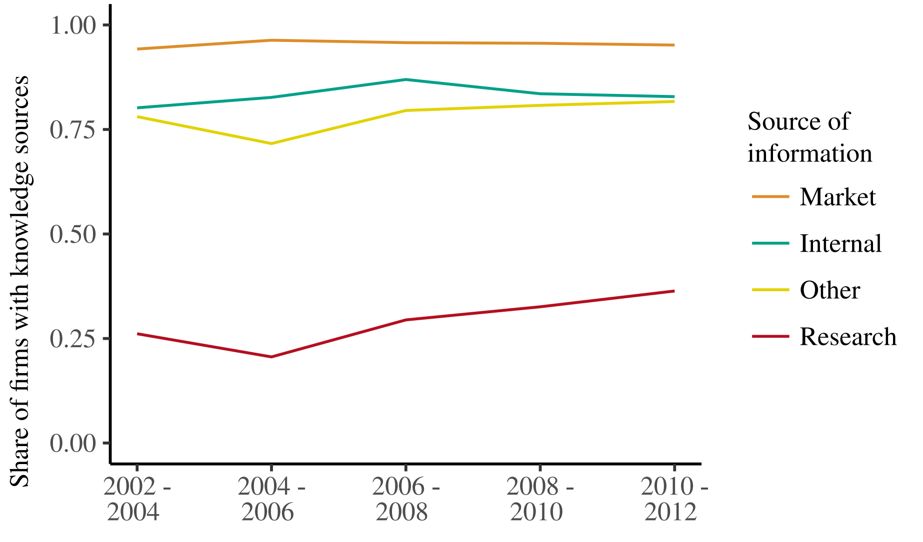

Figure 5.9: Information sources while engaged in innovative activities. n = 4811.
Source: Innovation Data (2018)

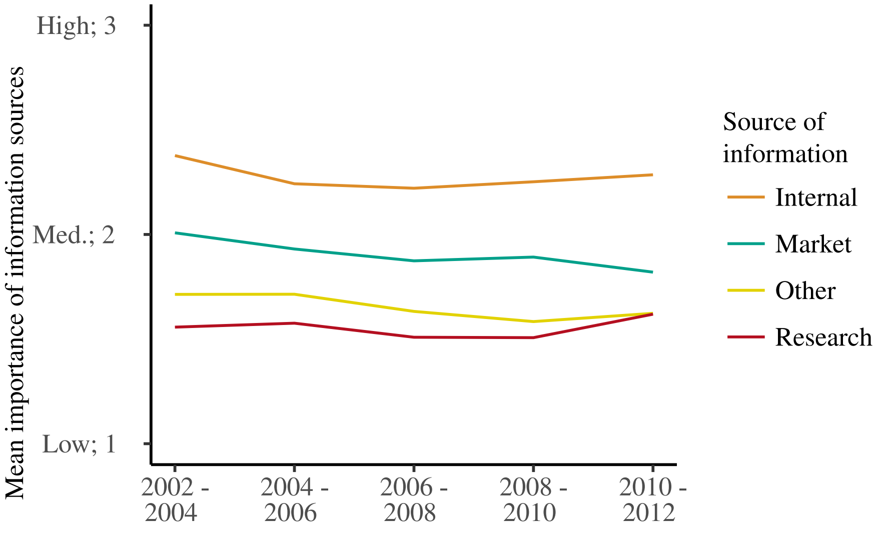

Figure 5.10: Mean importance of firm information sources while engaged in innovative activities. n = 4811.
Source: Innovation Data (2018)

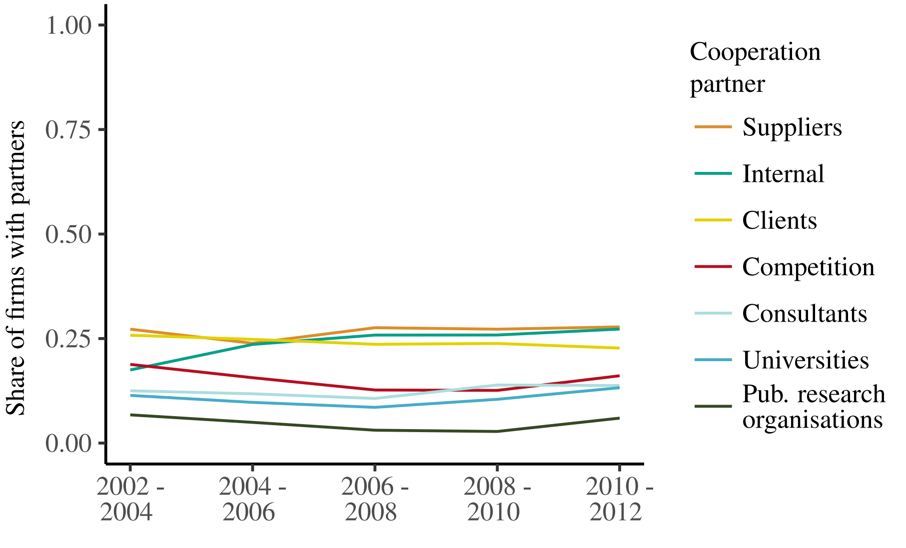

Figure 5.11: Share of firms that cooperated on innovative activities with partners. n = 4811.
Source: Innovation Data (2018)

One indication of firm attitude towards innovation is innovation intensity, usually defined as the share of turnover from innovations in total turnover. Figures 5.12 and 5.13 show innovation intensity of innovations that are new to the firm's market and new to the firm itself. Note that on both of those graphs, n = 3030. Innovation intensity is asked only from firms with new products or services. If the firm only had process innovations, innovation intensity is unknown. Firms without innovations are naturally at 0. Figures 5.12 and 5.13 are kernel density plots, akin to a smoothed histogram.

One caveat of the CIS is visible in innovation intensity graphs. When firms are asked to estimate a share of something, human nature is to give rough estimates. On graph 5.12, even with smoothing, there are visible bumps on round numbers. Most firms answer this question in multiples of 10.

As seen on 5.12, innovation intensity for most firms is not high — less than 25%. About half of firms declare zero innovation intensity. The innovation intensity for new-to-firm innovations is higher, about 18% of firms declare zero. This can be puzzling, since one of the important aspects of an innovation is commercialisation, it is not an invention. If 18% of firms say they have new products or services, but they receive zero turnover from these innovations, what are the qualities of these innovations? These can be very new, at the early phase of commercialisation or even prototypes. Unfortunately, it is not evident in the CIS which type of innovations these are.

What is evident is that firms realistically estimate that turnover from new-to-market innovations is harder to come by than new-to-firm innovations. For example, about 3% of firms declare innovation intensity of new-to-market innovations higher than 50%. The same estimate is about 14% of firms for innovation intensity of new-to-firm innovations.

Innovation intensity is one aspect that indicates firm innovation strategy. As described in Chapter 2.4, innovations are a possibility to create firm-specific competitive advantages. Firms with high innovation intensity over a long period create new innovations constantly. Their business strategy revolves around creating new products or services. Firms with constant low innovation intensity aim for competitive advantages in other aspects, such as minimising costs or opening new markets.

There seems to be no indication that innovation intensity for both new-to-market and new-to-firm innovations depends on business cycles when Figures 5.12 and 5.13 are compared. All CIS waves used in the analysis seem to be roughly at the same position.

Figures 5.14 and 5.15 highlight the share of firms and mean importance of objectives for product and process innovations. This aspect of firm innovation strategy

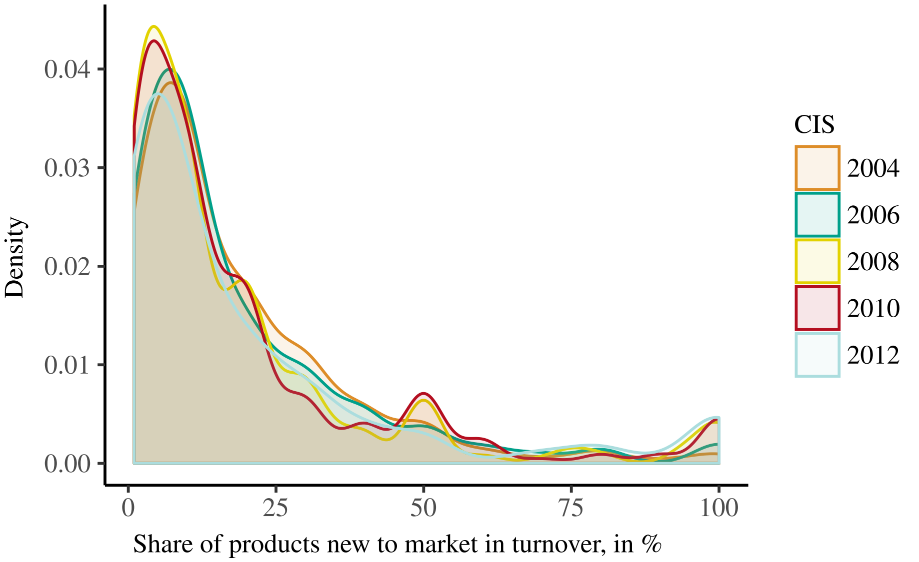

Figure 5.12: Innovation intensity of new-to-market innovations. n = 3030.
Source: Innovation Data (2018)

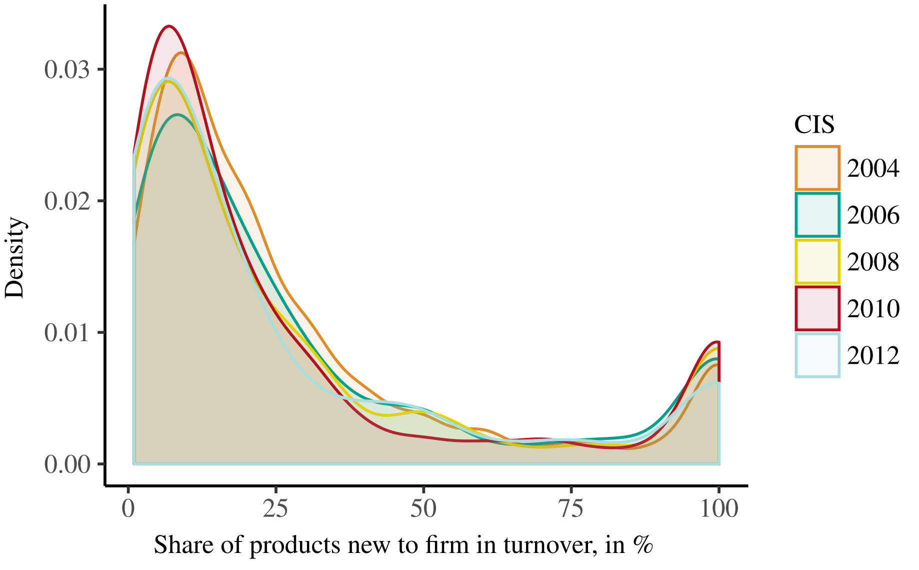

Figure 5.13: Innovation intensity of new-to-firm innovations. n = 3030.
Source: Innovation Data (2018)

has been rephrased several times between CIS2004 and CIS2012. However, three main categories have been constant for innovative firms during this period. These are the objectives to: (a) improve flexibility for producing goods or services; (b) enter new markets or increase market share; and (c) widen the portfolio of goods and services offered.

Figure 5.14 shows the share of firms that indicated that these objectives are at least of low relevance. Only firms with innovations answered the question. The share of firms that have an objective to open new markets is slowly decreasing. At the same time, a wider portfolio is slowly increasing. Flexibility as an objective has the highest share of them. Estonian firms are mostly relatively small compared to any bigger nation. Flexibility is a known strategy for small firms, able to offer custom products for their clients. Without other context, Figure 5.14 seems to indicate that firms in the CIS sample are oriented towards creating new products and services without entering new markets.

Figure 5.15 shows the importance of these objectives, only for the firms which declared them as somewhat important. The graph presents the mean score of respondents. When compared to results from Figure 5.14, the mean importance of widening the portfolio objective is slowly decreasing. An increased number of firms indicate it as an objective, but the mean score is getting lower. This indicates that it might not be the most important part of firms' objectives. Flexibility in production is slowly becoming more important to firms overall. Entering new markets has a relatively stable trend during these years.

Firms' objectives are slowly changing over time. However, cyclical changes are not visible on the macro level from firms in the CIS sample.

Table 5.3 shows the formal appropriation methods used by the firms in the CIS sample. The calculation shows the rate per 1000 firms. These are based on the official Estonian Patent Office data and are intellectual property rights awarded, not applied. Description of these types is in Chapter 4.3.

Even though innovation output statistics show a relatively small decline over these years for the same firms, there is a significant drop in years 2006-2010 for most formal intellectual property rights. Trademarks show a small constant decline over the years.

Patent awards have gone up in the last period. This is due to a few outlier companies, two of which received seven patents each in the last period. This example also shows the extent to which Estonian statistics on intellectual property rights are affected by a few companies. All patents in the last period for firms in the CIS sample are awarded to only ten firms. Similarly, industrial models and industrial designs are awarded to about ten firms in every period.

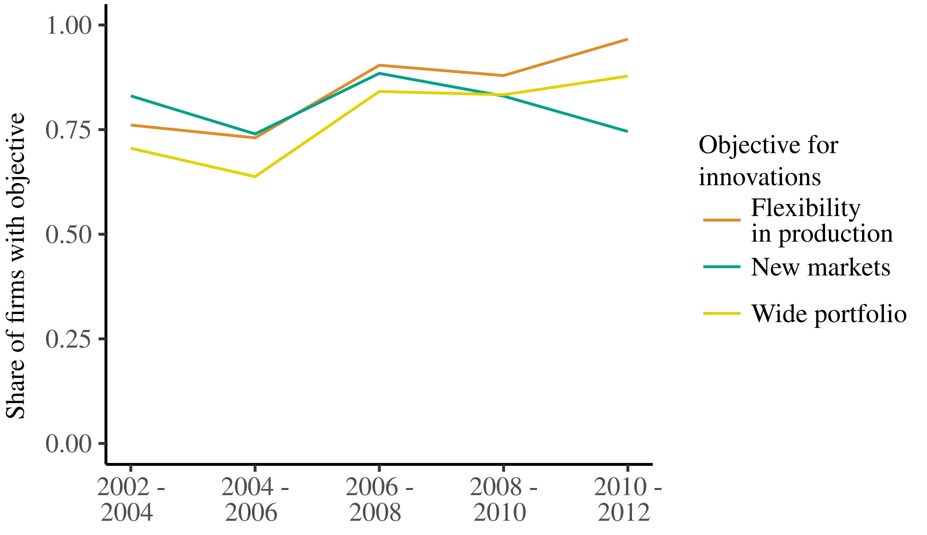

Figure 5.14: Share of firms that indicated some relevance to objectives for product and process innovations. n = 4811.
Source: Innovation Data (2018)

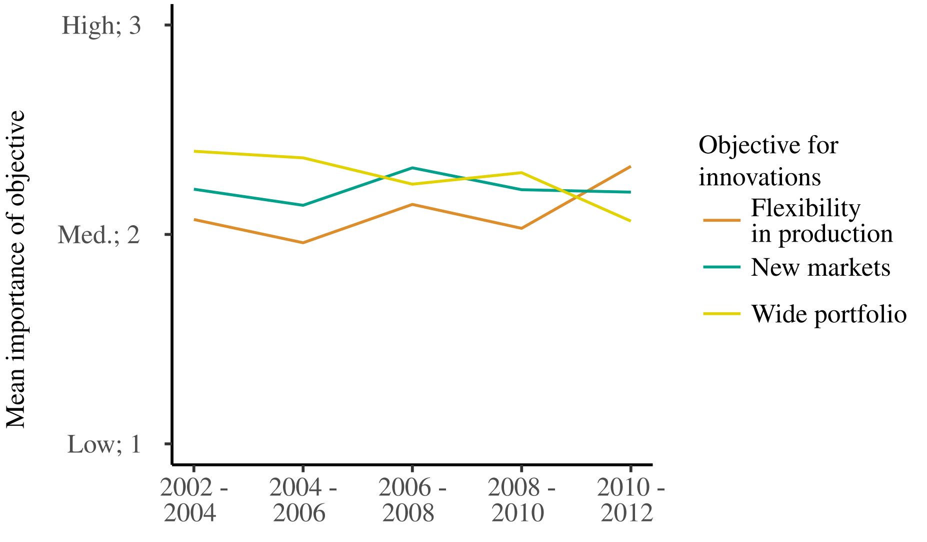

Figure 5.15: Mean importance of objectives for product and process innovations. n = 4609.
Source: Innovation Data (2018)

Because firms in the CIS sample are not patenting or using other methods more apt in manufacturing industries to protect their intellectual property, a combined variable for industrial models, industrial designs and patents is used, labelled as formal appropriation methods. Trademarks are separate entities.

Based on these numbers, it is already certain that for almost all firms in the CIS sample, patenting is not the choice of strategy considering appropriation methods. CIS2012 has been the first CIS where a set of questions regarding competitiveness of product and process innovations was asked. In the Estonian CIS sample, the share of firms considering trademarks, lead time advantages and complexity to be an important part of strategy was three times higher than for other forms of appropriation. Other categories included patents, industrial designs, industrial models, copyrights and secrecy. For example, about 4% of firms (with innovations) regarded patents to be important for the competitiveness of their innovations. Using external data from the Estonian Patent Office, about 1.3% of firms from the CIS2012 innovative firms sample have been awarded patents. There is a small mismatch. This may be because not all patents are awarded, there may be some time-lags involved, and some patents are only applied in specific markets which might not include the EU. Similarly, firms answering that trademarks are at least somewhat important for their innovation competitiveness is higher in the CIS2012 survey than the result from the Estonian Patent Office data suggests. About 45% of firms indicate trademarks to be at least of low level importance for their competitiveness (as opposed to not having used them). However, the Estonian Patent Office database of awarded trademarks reports roughly 19.5% for the same firms.

Unfortunately, this set of questions has been surveyed only once, in CIS2012, and there are no other CIS samples for comparison. This is the first indication that external data can and should be used with CIS data, since there might be some discrepancies involved. Otherwise, at the very least, when firms respond that the level of importance is high in their strategy options, it might not always mean that they have managed to actually use these methods.

On the whole, firms in the CIS sample probably rely more on informal appropriation methods in their innovation strategy, such as lead-time advantages, complexity and hard to copy products, secrecy, know-how and other methods. Unfortunately, there are no good ways to estimate these for the CIS sample using available data. So far, data is only available for formal methods, which can only give half of the picture.

Firms in the CIS sample tend to have some repetition. Already visible in Appendix II, there is a subsample of firms on the whole for which there is information in every CIS period. Figure 5.16 shows firm age in years at the end of the CIS period, as calculated based on the founding date from the Business Register. There are

Table 5.3: Intellectual property rights use in the CIS sample over time, per 1000 firms.

CIS	Industrial models	Industrial designs	Patents	Trademarks
2002 - 2004	24.0	16.6	1.1	230.7
2004 - 2006	15.1	27.0	1.0	309.8
2006 - 2008	3.9	8.9	0.0	283.8
2008 - 2010	9.2	10.4	4.0	225.4
2010 - 2012	18.0	6.4	18.0	203.1

Source: Innovation Data (2018), n = 9155.

19 observations in the CIS sample for which there is no founding date available. Some of them have not submitted their annual reports.

The average age of firms in the CIS sample is increasing in every CIS wave. This is mainly because Estonian firms have been founded around 1991 at minimum. The Estonian Business Register does not have continuity in firm age from the Estonian Soviet Socialist Republic times, even if any of the planned economy firms may have survived.

In the context of innovation strategies, if there is a difference for managerial choices for older and younger firms, these can only become wider with each CIS wave. In the early CIS waves, most firms were fairly young. By comparison, in most European countries, firms are just as young in the later CIS waves. There are no truly old firms in the Estonian CIS sample, simply because they do not exist in Estonia. This must be taken into account.

Figure 5.17 shows fixed assets per workers on balance in log values. This is the total count of observations, meaning that firms which have participated in the CIS several times are counted several times. Log value is used because assets on balance per worker have extremely long tails. For example, the median value of tangible assets on balance per worker is 7844 euros for firms in the CIS sample. The maximum value is more than five million euros per worker. The median for intangible assets on balance per worker is 0 euros.

Figure 5.17 does not display firms which do not have any fixed assets on their annual reports. Very few firms are missing for reasons unknown — altogether 128 observations. For 538 observations, there are no tangible assets or total fixed assets, and for 6307 observations, there are no intangible assets on the statement of financial position. The histogram does not display these firms, since they skew the graph very high with 0 value on the left side, up the count of 6307.

The average position of tangible assets is much higher than intangible assets. The firms investment position is clear. In most cases, tangible assets tend to be more expensive until enough brand equity or know-how has been acquired. For example, tangible assets include construction, machinery, offices, etc. Intangible assets include patents, brand value, development expenses, firm value, etc.

There are no trends visible when Figure 5.17 is plotted with five facets, each for every CIS wave.

Annual report data about firm assets per worker represents stocks, not flows. Investments are included in the CIS which are one side of the strategy position, the types of investments firms do in their innovative activities. Stocks represent the firm's overall position, whether they are more reliant on capital or labour. Firms with very high fixed asset stocks are typically manufacturing firms with expensive machinery and facilities, whereas firms with high intangible assets rely on knowledge or design stocks.

When business investment and innovation statistics are compared, there are some important differences. Firm investments in R&D related activities are less cyclical when compared to investments in machinery and other tangible assets. Firms relying on these types of activities in their innovation strategy might be able to shift their strategic choices more easily. Investments in R&D related activities should entail more capability building — investments in human capital — and firms might engage in more long-term projects.

Data described in this chapter is also used to estimate firm innovation strategies and describe possible choices.

5.3. Public sector support, 2002 - 2012

This section describes public support given to firms in the CIS sample. The data sources are described in Chapter 4.2 and the typology of instruments in Chapter 3.

Firms in the CIS sample were beneficiaries of 22 different paying agencies between 2002 and 2012. There were 3502 unique firms in the CIS sample, of which 1678 received some kind of public support. These 1678 firms received about 1.1 billion euros in public support altogether.

The full list of paying agencies handing out at least one instrument to at least one beneficiary is in Appendix III. The table also highlights the number of instruments, number of different policy types, number of beneficiaries and total sum eligible for the beneficiaries included in this analysis in the period between 2002 and 2012. The full list corresponds only to firms in the CIS sample. Many of these paying agencies have a much more extensive list of instruments and total sum of euros delivered to beneficiaries than the CIS sample covers.

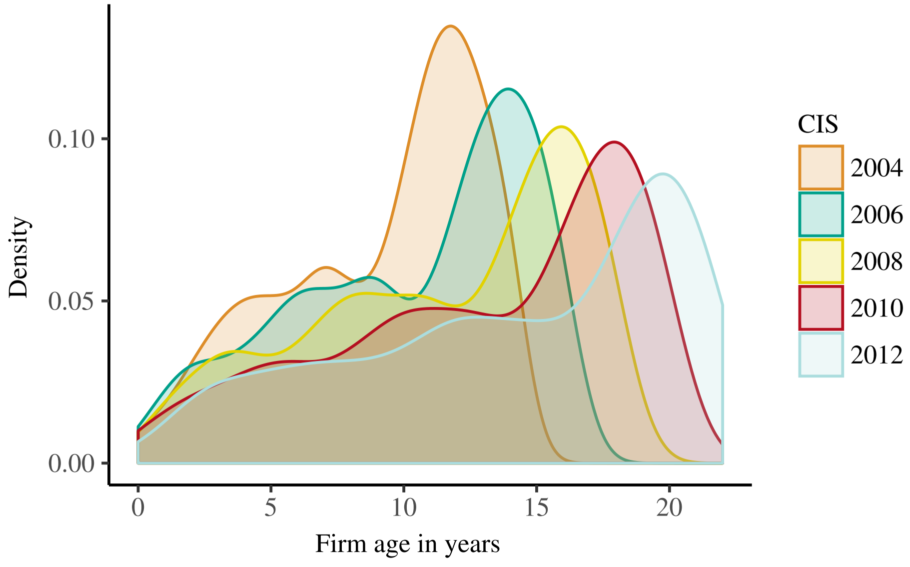

Figure 5.16: Firm age in years. n = 9155.
Source: Innovation Data (2018)

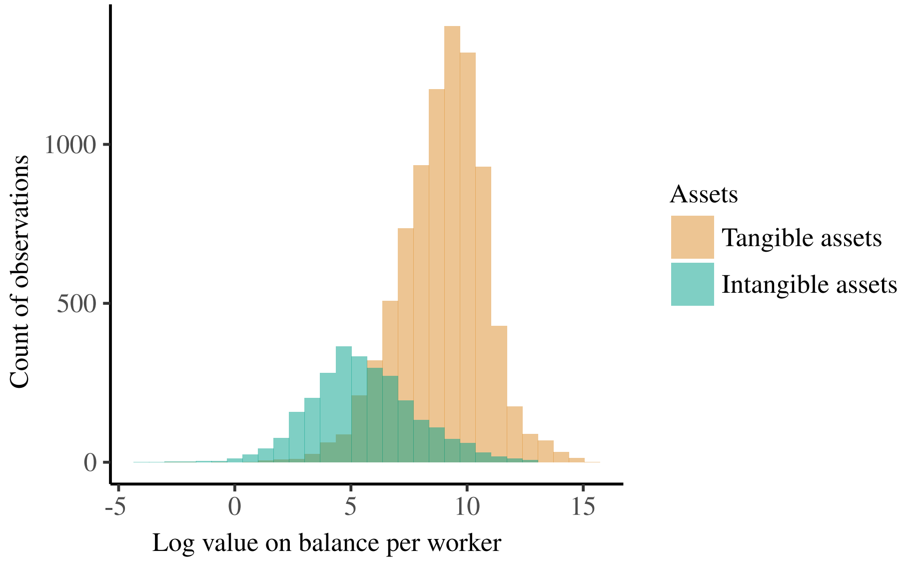

Figure 5.17: Fixed assets per worker. n = 9155.
Source: Innovation Data (2018)

Table in Appendix III highlights some important aspects about public support in Estonia. There are paying agencies that deal with many beneficiaries and instruments. These are the main paying agencies in Estonia, for example, Enterprise Estonia, Agricultural Registers and Information Board, Environmental Investment Centre and others. A brief description of these is in Chapter 4.2. These paying agencies are responsible for instruments in entrepreneurship policy, environmental policy, rural life policies, social policies and regional policy. These agencies have a wide selection of instruments for which they are responsible and are also responsible for several different policy types when compared with the typology of instruments developed in this thesis.

However, there are also paying agencies that cater to only a select few beneficiaries, but the total sum of support funds can be very large. This is not a coincidence, such as that most firms catered to in this way are not covered in the CIS sample because these paying agencies deal with either very large infrastructure projects, such as regional airports or municipal infrastructure, or within a very specific niche. One caveat of the CIS is that it does not cover firms with main economic activities in the primary sector. Therefore, some paying agencies, e.g. Estonian Private Forest Centre, are represented with very few beneficiaries.

In addition, some of these paying agencies hand out direct subsidies for very specific national services which are motivated by public goods rationales, hence they have a very short list of beneficiaries. Examples of these are usually ministries.

Table 5.4: Total use of instruments by the CIS sample

CIS	Firms	Beneficiaries	Sum in EUR	Paying agencies	Instruments	Instrument types
2002 - 2004	1747	200	22 319 850	3	19	4
2004 - 2006	1924	449	37 603 415	6	21	5
2006 - 2008	2026	408	198 153 861	11	39	8
2008 - 2010	1735	1032	549 465 443	16	51	10
2010 - 2012	1723	1154	299 505 738	20	70	10

Source: Innovation Data (2018), n = 9155.

Table 5.4 shows the main points about public sector support in the CIS sample. The number of beneficiaries has been rising with every CIS wave, and the total sum that is eligible for beneficiaries has also increased. The peak in sum is between years 2008 and 2010, which corresponds to some very large infrastructure projects financed by public money, the largest of which was in excess of 67 million euros.

Similarly, the number of instruments and instrument types is also increasing with every CIS wave. Estonian policy domains have increased in width, as more instruments can be found that aim public intervention toward private business. This adds to the complexity in public policy analysis.

Figure 5.18 displays the number of beneficiaries per instrument over time. There are two additional lines on the graph. A dotted line to display the total number of unique firms which are beneficiaries in every period and a dashed line to display the total number of firms in the CIS sample during this period. Firstly, it is obvious that the average number of instruments among firms which are beneficiaries is more than one and rises with every period. This means that in the CIS sample, it is already observed that there can be additive effects for beneficiaries from several instrument types.

Secondly, in the Estonian CIS sample, the share of firms who are beneficiaries is rising rapidly. In the last period, the average use of instruments per firm, even for the whole sample, is more than one. If the share of firms which are not beneficiaries is becoming closer to zero, there may not be any counterfactuals left for any type of analysis.

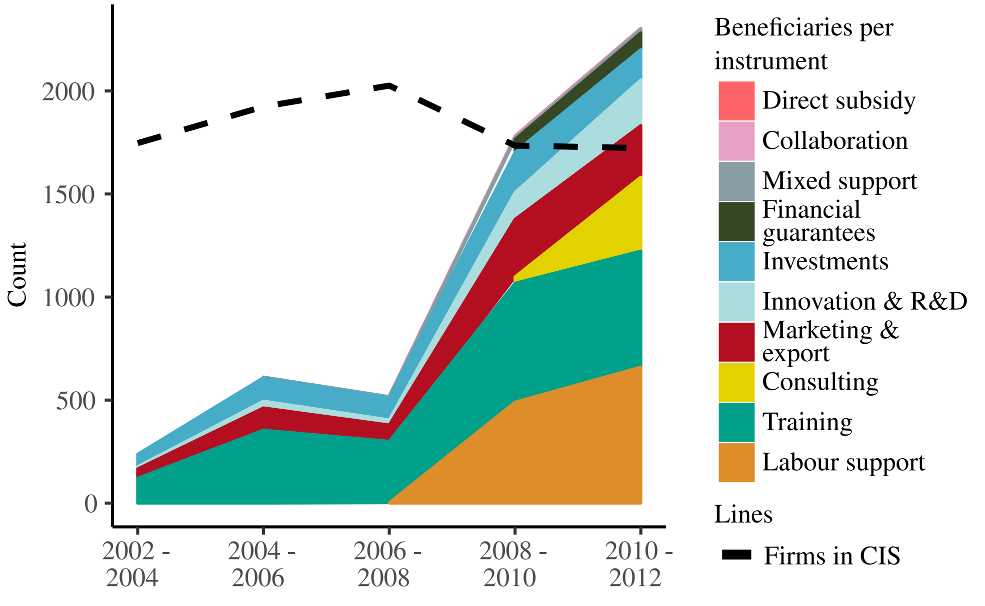

Figure 5.18: Beneficiaries per instrument over time. n = 9155.
Source: Innovation Data (2018)

Figure 5.18 displays the use of instruments by firms. This means that for every firm, there is a binary response, whether they were a beneficiary from a single instrument type. Even if they were a beneficiary multiple times during a single period, it would still count as one. Similarly, if they were a beneficiary to multiple instruments within an instrument type, it is still counted as one.

In the CIS sample, the most frequent instruments are dealing with labour support and training and skill development. These are relatively cheap instruments where cost per beneficiary is small. Marketing and export development, investments and innovation and R&D instruments have been available as well for all periods. Direct subsidies, collaboration instruments are relatively rare in the CIS sample. These instruments are catered to firms with national goals or which are part of international business and science networks. There are not many firms with these objectives in the CIS sample. However, these instruments can be costly per firm. Hence, the possibility to apply or be part of the financing scheme is also smaller. Mixed support caters mostly to starting ventures, which are not the main focus of CIS. The CIS sample consists of firms with more than ten employees, which may cut off the majority of firms that receive mixed support or are part of incubators.

It is apparent that the Estonian policy instrument mix is becoming wider in every period. There are more instruments available and more finances available. The possible effects from public support to firms becomes more complex as well.

Figure 5.19 displays the same data, but with total sum per beneficiary over time. Now the majority of Estonian instruments used becomes clear — it goes to investments. By ratio, it ranges between 65% and 95% of funding in the CIS sample.

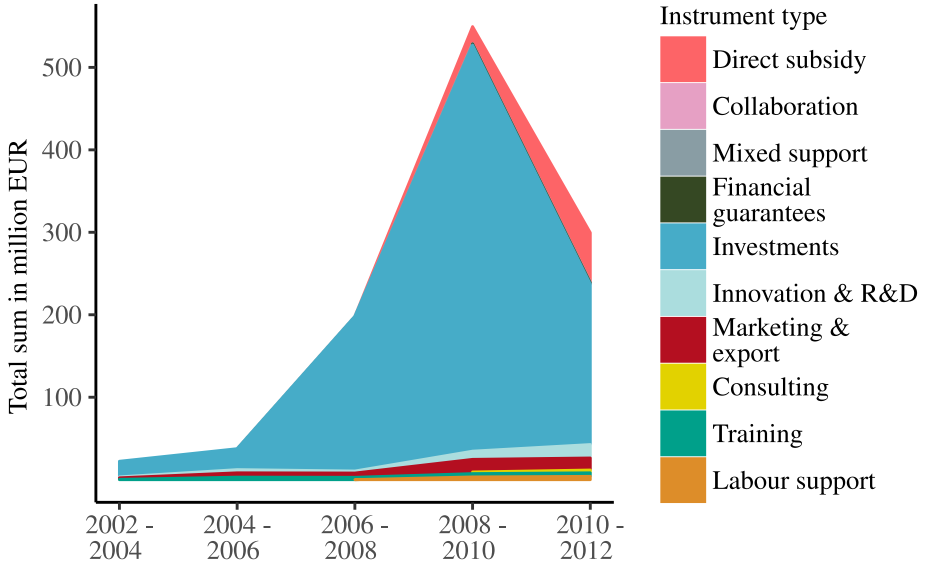

Figure 5.19: Total sum to beneficiaries per instrument over time. n = 9155. Source: Innovation Data (2018)

Figures 5.18 and 5.19 highlight also the difficulty for analysis. If the object of interest is the use of instruments, the ratio between different instrument types is much more even. The possible effect can stem from a variety of different instruments. However, if the sum of finances is used in modelling, the variance is large. The effect of one additional euro for investments is probably much less than one additional euro for consulting. In addition, investments for small and large firms also differ, depending on the amount of fixed assets already on balance and possible financing capabilities. Most of these instruments are co-financing, meaning that the firm has to finance the majority of the project from their own funds. This sets limits for comparability between firms of different sizes. The use of instruments does not have these issues. In essence, the difference is whether the object of interest is participation in the instrument or the financing effect of the instrument.

Some instrument types are very rare; collaboration instruments and direct subsidies have less than 20 observations between them. Mixed support has also fewer observations than other types. Due to scarcity of data points, these instrument types are combined into a single category labelled as 'other'. Since there are no exact limits on where to set the cutoff value on scarcity, these three have been combined in the analysis based on subjective opinion. In the descriptive statistics described here, they are individually presented as before.

Appendices IV and V are tables of the underlying data shown in Figures 5.18 and 5.19, respectively.

External data about public sector support illustrates the combined use of instruments. If there are possible compounding or conflicting effects in the instrument mix, they are not available in the original CIS.

Table 5.5: Combined use of instrument mix, number of beneficiaries by simultaneous participation in instrument types

	Amount of simultaneous instruments							
CIS	0	1	2	3	4	5	6	7
2002 - 2004	1547	165	33	2	0	0	0	0
2004 - 2006	1475	319	99	29	2	0	0	0
2006 - 2008	1618	315	74	19	0	0	0	0
2008 - 2010	703	558	282	124	53	14	1	0
2010 - 2012	569	545	281	179	95	44	9	1

Source: Innovation Data (2018), n = 9155.

Table 5.5 shows the combined use of instruments. The numbers in the header are the sum of simultaneous participation in different instrument types within the CIS period. This calculation is based only on the level of instrument types. If a firm participated in two different types of instruments — for example, investment instruments — it is counted as a single type. Therefore, there is a single firm which managed to participate in seven different instrument types within a single period.

The possibility for interactions between multiple instruments is high. In CIS2012, 35% of the firms were participating in more than one policy instrument as a beneficiary. These cases are not rare, yet there is virtually no empirical literature about possible policy effects in these cases.

The possible combinations of different instruments is also large. In this thesis, instruments are grouped into ten instrument types. There are 45 possible two-way combinations, 120 possible three-way combinations. It is not feasible to analyse all combinations separately.

If policy instruments are becoming more popular, they are recognised as a tool by both the public and government, this increase in instrument mix will continue. Even in the CIS sample, there are very few beneficiaries in CIS2004, but there is already a proportion of firms which are participating in more than one instrument simultaneously.

A second effect might be that firms specialise in acquiring public support. If the most prominent instruments lower the cost of investment or worker training, firms might learn how to use these instruments to their advantage repeatedly, as a form of extracting rents when policy instruments are widely available.

Table 5.6 shows the lower matrix and the diagonal of all two-way combinations of simultaneous participation in different instrument types for the CIS sample across all years. The diagonal represents the total use of these instruments, in combination or single. The lower matrix is the combined use of two corresponding instruments. If a firm participated in three or more policy instruments simultaneously, these are calculated as multiple sets of pairs.

There seems to be no distinct pattern of instruments being used hand-in-hand. For most instrument types, there are beneficiaries who have been part of all other instrument types as well. For example, there are no patterns for soft instruments such as consulting or marketing support specifically catering to firms which are also participating in investment instruments. Soft instruments are also combined with others, as are other more investment and financing instruments.

This indicates that firms are varied in their choice of instruments. Firms are also participating in instruments according to patterns which are not easily described. Datasets where we only observe whether firms have participated in any type of policy instruments without exact details in which policy instruments the firms where actually beneficiaries of might lose some important effects.

In addition, empirical papers where public sector support is binary, or only one type of instrument has been gathered, might severely underestimate possible in-

Table 5.6: Lower matrix of two-way combinations of participation in different instrument types across all years

	Col.	Con.	Dir.	Fin.	Inn.	Inv.	Lab.	Mar.	Mix.	Tra.
Collab. prog.	12									
Consulting	2	390								
Direct subsidy	0	2	5							
Financial	2	32	0	143						
Innovation	4	102	0	20	421					
Investment	3	60	0	28	69	624				
Labor support	4	193	4	78	119	134	1152			
Marketing	4	159	2	50	159	149	238	761		
Mixed support	0	11	0	6	4	1	15	7	35	
Training	5	267	4	74	254	307	438	455	14	1913

Source: Innovation Data (2018), n = 9155.

teraction effects from other policy instruments. In this CIS sample, there are hundreds of firms that have received support in some form of consulting and also some investment aid. Which of these is causal to creating innovative activities is difficult to infer.

There is also a question in the CIS survey about receiving public support. Table 5.7 is a comparison between CIS response to whether firms received public support during their innovative activities and external data. In the CIS, firms are asked whether they received public support from the local government, national government or EU level. All these categories have been combined, and the firm receives a positive response if any of them applies. In the external data, all instrument types have been combined together. In the CIS, firms that declared themselves as not innovative did not have to respond to this question.

With external data, it is not always evident if these instruments actually support innovativeness. This is also under analysis in this thesis, and some evidence can be found in section 7. However, even if some of these instruments are not related to innovativeness, there seems to be some under-reporting in the CIS. For example, in the CIS2010, there is a difference of 400 firms which did not indicate receiving any public support but can be found in the external data. The underlying causes are not clear for inferring whether firms feel that public support has been irrelevant to innovative activities or whether there are some other reasons for under-reporting.

To conclude, description of the past behaviour of firms in the CIS sample shows some trends. Business statistics seem to be more affected by business cycles than R&D statistics. Estonian firms overall have become more complex as they have become more accustomed to competing with other EU firms. At the same time,

Table 5.7: Comparison of CIS response to receiving public support and external data

CIS	Firm status	observations	CIS	external data
2002 - 2004	not innovative	844	0	49
2004 - 2006	not innovative	856	0	114
2006 - 2008	not innovative	892	0	100
2008 - 2010	not innovative	799	0	378
2010 - 2012	not innovative	953	0	567
2002 - 2004	innovative	903	100	151
2004 - 2006	innovative	1068	127	335
2006 - 2008	innovative	1134	160	308
2008 - 2010	innovative	936	254	654
2010 - 2012	innovative	770	259	587

there is an influx of public policy instruments aimed at solving problems within firms, whether it is human capital, lack of physical capital or increasing productivity. Descriptive statistics have been drawn from the dataset and used for the rest of the analysis as well. As is clear, CIS data is not without faults. At the same time, it is the most informative and comprehensive survey about innovative activities available in the EU.

6. DYNAMICS OF FIRM INNOVATION STRATEGIES

The structure of this chapter is as follows. First, I explain the aim of this chapter, the research questions and objectives and describe where they fit into the theory provided in Chapters 2 and 3. Second, I explain the method used to reach the objectives. Third, I estimate, interpret and discuss the results.

6.1. Objectives and motivation for estimations

The aim of this chapter is to estimate the dynamics of firm innovation strategies. Information about firm choices while conducting innovative activities are aggregated to create constructs of firm innovative behaviour. Firms are combined into groups based on homogeneous innovative activities. These groups are called patterns of innovation — combinations of the most prominent innovation strategies. In the end, firms can have multiple innovation strategies concurrently, but they belong to a single pattern of innovation.

The research questions in this chapter are the following. First, what simultaneous firm-level choices in the innovation system create visible innovation strategies? Second, what patterns of innovation exist when firms are clustered based on their innovation strategies?

The objective of this chapter is to: (i) answer research questions one and two; (ii) estimate innovation strategies and patterns of innovation for Estonian firms; (iii) describe the dynamics of patterns of innovation; (iv) store estimates of patterns of innovation for every firm to be used in the analysis of the effects of policy instruments to patterns of innovation in Chapter 8.

Chapter 2 describes possible mechanisms for firms to reach their innovation strategies. Technological regimes suggest that firms are influenced by their sector and the underlying technological knowledge within this sector, creating a trajectory for firms. This technological trajectory is available to most firms within the sector, since they rely on similar knowledge, technological advancements and demand for innovations. This suggests that firms are free to choose actions within some scope, but there should be prominent major strategies visible within sectors, and successful firms remain broadly in these strategies for longer periods. Shifts are possible when new technologies are invented and, in the end, a whole sector slowly shifts toward this new technological trajectory. Detailed description is in Chapter 2.1.

Another possible mechanism for firms to reach their innovation strategies is developed based on management choices, how firms are managed to be successful over a long period. In short, firms need competitive advantages, something that makes them more attractive on the marketplace. This is close to the notion of a Schumpeterian entrepreneur who seeks monopoly rent on the marketplace based on innovations. Recent theories suggest that firms need dynamic capabilities, meaning that they should reorient their strategies often, depending on their own capabilities and market reactions. These theories would suggest that firms change their innovation strategies as often as is necessary for them to be strong competitors. Detailed description is in Chapter 2.4.

Both theories of the innovation process expect some path dependencies based on best behaviour, hinting that there can be optimal strategic choices on the firm level. However, it remains unclear how firms can figure out this optimal behaviour *ex ante*.

The method section in this chapter describes in detail how dynamics are taken into account in the estimation for innovation strategies in order to be comparable over time. As described in Chapter 2.3, some dynamics of innovative activities and, therefore, choices in the innovation system are to be expected for a single firm. Firms get older, and there are learning-by-doing effects as successful firms have more credibility and less credit constraints. These and other effects all influence possible choices in the innovation system — what kind of capabilities the firm can have, what kind of barriers to innovation the firm has, and other elements — which evolve over time for a single firm.

Data used for the estimation of firm innovation strategies and patterns of innovation is described in Chapter 4.

Patterns of innovation are relevant for policy making and have potential use in industrial and innovation policy (Archibugi, 2001). Since patterns of innovation aggregate firms into homogeneous groups based on innovative behaviour, they can be more specific than policies based on sectors of economic activities. The latter can be very heterogeneous in their actual activities. In Estonia, firms that develop garden houses and modular wooden smart houses are in the same sector based on economic activities, but their innovative behaviour can differ greatly.

The most prominent type of estimation for patterns of innovation is the OECD high-tech-low-tech classification (Hatzichronoglou, 1997). It has been incorporated into national statistics and is a constant basis for policy making and indexing of innovativeness. However, it relies on R&D intensity only.

The OECD classification has been criticised for arguably influencing policy making too much to cater only to high-tech firms (Hirsch-kreinsen et al., 2003; von Tunzelmann and Acha, 2005). Von Tunzelmann and Acha (2005) argue that low-tech firms have different innovative behaviour and contribute just as much to overall economic welfare. A search for specific low-tech firm based growth in Europe has been without results (Heidenreich, 2009). However, results from Heidenreich (2009) show that there are behavioural differences between high-tech and low-tech firms, which is also under investigation in this thesis.

Patterns of innovation are, therefore, relevant for understanding the innovation process. Patterns of innovation can be used to analyse key differences in determinants of innovation, levels and types of innovative efforts and relationships between performance, and technology and innovations (Bogliacino and Pianta, 2016). They provide one meaningful basis on how to create understandable groups of firms, which share some underlying behavioural traits.

6.2. Two-step estimation with EFA and k-means

There are no agreed upon strict definitions on how innovation strategies and patterns of innovation are estimated. Two fairly recent overviews of methods found in the literature point to very different directions (see De Jong and Marsili (2006) and Frenz and Lambert (2012)). De Jong and Marsili (2006) include a wider categorisation, where patterns of innovation range from Pavitt's taxonomy (1984) to the high-tech-low-tech categorisation used by the OECD (Hatzichronoglou, 1997). Methods include both quantitative and qualitative analysis, mean testing, ANOVA testing of groups, etc.

Frenz and Lambert (2012) give an overview of a set of papers which rely on two-step analysis, where relevant variables are first reduced in dimension with some type of factor analysis and then clustered. They point out that even when similar methods are applied, the comparability of results needs to take into account: (i) the methodology; (ii) the measures or variables used in the analysis; and (iii) how and where the data is gathered.

The most frequent approach is to build on two steps. First, relevant dimensions of the innovation process within the firm are reduced in dimension to form coherent innovation activities or innovation strategies. These are sets of actions which are usually concurrent within the firm. These strategies are not exclusive. Firms may use several strategies at the same time. Second, these strategies are then clustered together in a way that some groups form. Now, we get a single estimate for a firm of which group it belongs to. These groups are based on what strategies are mostly applied together by firms. There is no specific rule or strict number of strategies and groups that can be formed.

This thesis builds upon these two-step analyses and expands them to a dynamic setting. The reasoning to adopt this approach is the following. First, without presupposing innovation activities and forming factors, it is possible to build upon what firms are actually doing — a so-called data first perspective. Second, this approach is more common to estimate patterns of innovation which rely on a wider set of innovative activities. Third, this approach is more common in recent empirical works. Fourth, there is an aspect of comparability with other papers. However, as pointed out already, it has its dangers as well.

The first step of the method applied in this thesis is to reduce variable dimensions with exploratory factor analysis (EFA). EFA is a method to construct latent variables. With EFA, we believe that the variables used in the analysis are part of some unobserved characteristics, each of them contributing to something measured indirectly. For example, we can measure if firms are spending on R&D, cooperating with universities and hiring academics. The latent construct would be how science based the firms' behaviour is. There is no direct measurement to this characteristic, but there are indirect proxies which can tell about the effect. With EFA, some measurements can overlap; some variables can contribute to several latent constructs at the same time.

Some researchers have opted to use principal component analysis (PCA) as the first step (e.g. De Jong and Marsili (2006), Filippetti (2011), and Marsili and Verspagen (2002). PCA is a variable reduction technique where observed variables are reduced to a smaller number of principal components which account for most of the variance in the original observed variables. Principal components are linear combinations of the original variables which maximise the variation. In total, the same number of principal components can be extracted as there are original variables. Then the principal components would account for all of the variance in the data as well.

Principal components in PCA are linear combinations. The first principal component accounts for the most amount of variance, the second less, and so forth. This means that the first principal component is a linear combination in a projection in geometric space that finds the largest variance between n-number of variables. Simply put, it finds two observations in the data, one with all variables with minimum values and another with maximum values, and projects the first principal component through these two points. This also means that on the principal scores, the minimum value is the firm which has the minimum value in every observable characteristic, and, on the other end, the firm with the highest values. The second principal component is orthogonal to the first one, the third one to the second one, and so forth.

This creates problems in step two, where principal scores or factor scores are clustered. If the first principal score accounts for enough variance, then clusters are divided on that plane. Cluster one would be firms with the lowest observable characteristics, and cluster n would be those with the highest. Simply put, we would order firms based on minimum and maximum values in the n-dimensional plane.

EFA creates factor scores which do not have this property. In EFA, an observed variable can influence several factors at the same time, accounting for more variance in both factors. Therefore, the estimates are more aligned in thinking with latent constructs. These latent constructs are innovation strategies which rely on several choices at the same time. EFA has been more common as the first step as well, e.g. Camacho and Rodriguez (2008), Frenz and Lambert (2009, 2012), Hollenstein (2003, 2018), Leiponen and Drejer (2007), and Srholec and Verspagen (2008). At the end of the first step, there are factor scores available for every firm, the exact number of which depends on the researcher. Each of these factor scores represents a strategy which is the combination of choices for the firm, inputs and outputs of innovative activities. Since firms can have multiple strategies at the same time, all these constructs are taken into account in step two.

EFA has been carried out with polyserial correlations and OLS to find the minimum residual solution[1]. Some authors use the Pearson correlation matrix and some polyserial, meaning that variables with less than ten units are calculated with a polychoric correlation instead. Polychoric correlation treats variables as latent continous variables and amplifies their correlation (Kolenikov and Angeles, 2004). A more recent study has shown that polychoric correlations might not always be the best fit and ordinal PCA can work with discrete data as well (Kolenikov and Angeles, 2009). With this dataset, I found that even though the correlation matrix and the factor scores are different with polychoric correlations, the clustering solution is similar. Factor scores calculated with a polyserial correlation matrix significantly increased the cumulative variance accounted for by factors with this dataset. Therefore, I opted for the polyserial correlation matrix.

Extracted factors are rotated with varimax rotation for easier interpretability. Factor scores are stored and used in step two.

Step two is a clustering exercise. The general idea is to combine firms into groups based on the strategies found in step one. Firms which are similar in their innovation strategies are combined into one group.

After the initial data reduction, k-means clusters are estimated. It is an iterative clustering technique where the first cluster means are chosen at random, and then all the variables are appointed to clusters and the means are re-calculated, iteratively reaching an optimal solution – within-group homogeneity and between group heterogeneity are maximised (Hair et al., 2014). As opposed to hierarchical

[1] Details in Psych package: https://cran.r-project.org/web/packages/psych/psych.pdf p.135 under *fa*.

clustering, k-means is better suited to deal with a large number of heterogeneous data, but there are no visual aids for choosing the optimal number of clusters.

Clustering solutions with clusters between 3 and 6 are compared based on interpretability and size of clusters. Solutions with very small clusters are not optimal, since they rely on some very niche characteristics of the innovation process which are unique to only a handful of firms. In the end, a clustering solution is chosen by the researcher, and it is always subject to some criticism.

The k-means clustering solution is calculated by Hartigan and Wong's (1979) algorithm. Initial seeds are chosen as random (seed is set in programming for replicability) and observations are distributed to clusters, maximising between cluster heterogeneity. It is an iterative algorithm. After every round new means for cluster centers are calculated and observations are distributed to their nearest cluster. The iterative solution is found when it reaches a stable solution and changes in observation distribution do not increase between cluster distance.

Papers cited here have all relied on cross-sectional data. Hollenstein (2018) has estimated innovation strategies in a panel setting using the same methods as in an earlier cross-sectional dataset (Hollenstein, 2003). He assumes that firms pursue only one type of innovation strategy. I assume that firms pursue multiple strategies simultaneously and they can change over time.

Methods for panel setting can use the same methods as in the cross-sectional data in this case. Since reducing variable dimensions with either EFA or PCA loses inevitably some variation in the original data, estimating new factors for every period would make factor scores incomparable over periods. Factor scores would retain information about different activities over time, based on general population averages. This means that firms relying on exactly the same activities over time could be classified into different clusters in the second step. This is not an ideal solution.

Using EFA in a panel setting without specifying any time controls means that the firm is entered into calculations multiple times. When all observable characteristics are the same over time, the factor scores are also identical for the same firm. Therefore, the firm would be perceived to have the same innovation strategies over time, which aligns with our interest.

After the clustering solution, a discrete variable for every firm in every period is available, describing the innovation pattern to which the firm belongs. This can then be modelled as an ordinary discrete variable.

This two step estimation is presented in Figure 6.1.

Descriptive statistics about the clustering solution are presented graphically with methods from discrete state analysis. Not very known for economists, these are

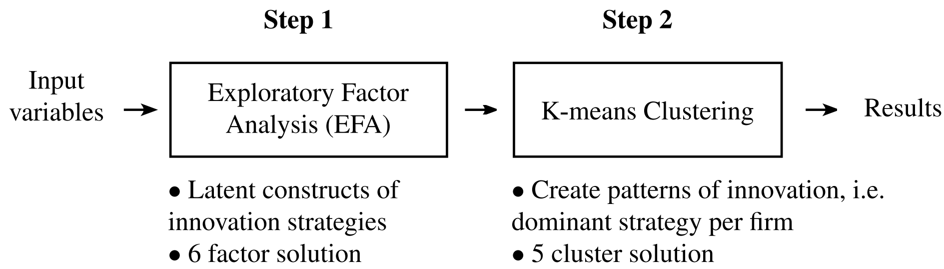

Figure 6.1: Two step estimation technique to estimate patterns of innovation for every firm.

helpful in plotting three-dimensional data where one dimension is discrete, meaning no ranking is logically superior to another. Discrete states have properties that shift from one state to another. I estimate state transition matrices for every pair of observations. These are basically transitional probabilities to change states, also known as Markov chains. Transition rates provide information about the most frequent state changes in the data and the diagonals in the matrix about the probability to remain the same state. For calculation references, see Gabadinho et al. (2011).

The solution from clustering is stored and used as an input in Chapter 8. Relevant dimensions are both discrete states and state sequences.

6.3. Estimation of dynamics of firm innovation strategies

This section describes the dynamics of firm innovation strategies. The estimation is a two-step analysis, described in Chapter 6.2.

The first step is EFA to reduce variable dimensions. Variables used to create the factor constructs are in Table 6.1 with factor loadings. The number of factors to retain is not exactly fixed. VSS test suggests three factors for maximum complexity. Parallel analysis suggests 8 factors. Other tests suggests factors ranging from 2 to 13. Therefore, there are no uniform answers with formal tests.

The factors have diminishing returns in explaining variance. The general solution is to retain factors if they have eigenvalues over 1, meaning they explain more variance than a single variable would. A second important criteria is that they are interpretable in some way. According to these criteria, 6 factors have been retained in the factor analysis. I analysed solutions ranging from 4 to 8 factors, and solutions above 6 created factor loadings which included uninterpretable results.

The Kayser-Meyer-Olkin index of sampling adequacy suggests that variables are meritorious to use in the analysis (Kaiser, 1974). Table 6.1 shows variables used to create latent constructs of strategies, factor loadings and communalities for every variable. Some variables have rather low communalities, such as the use of trademarks or training as innovative inputs. This means that factors do not explain most of the variance in this variable. Therefore, with this example, factors do not explain the variation in the use of trademarks. Either there are some other strategies that complement the use of trademarks, or they simply do not coincide with other values. One possible mechanism for low communalities is the lack of variance in the variable itself. For example, the average value for use of trademarks is high, but they have been used a lot by a small number of firms. Most firms in the CIS dataset do not have any trademarks registered.

Table 6.1: Standardized factor loadings matrix

Varimax rotated factor loadings

Variable	MR1	MR4	MR2	MR5	MR3	MR6	h2
sources: internal	0.08	0.24	0.20	0.15	0.01	**0.55**	0.43
sources: suppliers	0.15	0.06	-0.07	0.16	**0.68**	0.01	0.51
sources: universities	0.23	**0.67**	-0.08	**0.32**	0.08	0.10	0.63
sources: clients	0.14	0.11	0.30	**0.53**	0.06	0.08	0.41
sources: competitors	0.14	0.04	0.11	**0.75**	0.10	0.06	0.61
sources: conferences	0.09	0.28	0.10	**0.40**	0.30	-0.10	0.36
cooperation: suppliers	**0.82**	0.22	0.12	-0.04	**0.38**	0.12	0.90
cooperation: universities	**0.62**	**0.65**	-0.06	0.09	0.04	0.11	0.84
cooperation: competitors	**0.86**	0.10	0.08	**0.32**	0.05	0.10	0.87
cooperation: clients	**0.79**	0.19	0.25	0.17	0.09	0.15	0.79
cooperation: within group	**0.44**	0.07	0.11	-0.10	0.04	**0.78**	0.83
cooperation: consultants	**0.73**	**0.41**	-0.03	0.12	0.09	0.19	0.77
inputs: training	0.13	0.14	0.16	0.21	**0.34**	0.25	0.28
inputs: marketing	0.10	0.25	**0.60**	0.15	-0.04	0.11	0.46
inputs: outsourced R&D	0.28	**0.60**	0.02	0.15	0.11	0.24	0.53
inputs: internal R&D	0.20	**0.64**	0.19	0.17	0.01	0.19	0.55
inputs: acquis. machinery	0.05	0.00	0.01	0.00	**0.68**	0.01	0.46
inputs: acquis. knowledge	0.23	**0.34**	0.15	0.23	0.21	0.22	0.34
innovation intensity (to market)	0.13	0.23	0.22	0.07	-0.06	-0.03	0.13
innovation intensity (to firm)	-0.04	-0.11	**0.42**	-0.02	0.01	0.13	0.21
goal: capture new markets	0.08	0.17	**0.58**	0.17	0.12	0.01	0.42
goal: widen product portfolio	0.08	0.21	**0.76**	0.15	-0.04	0.07	0.66
appropriation: trademark	0.05	0.28	0.15	0.02	0.02	-0.01	0.10
appropriation: formal methods	0.02	**0.55**	0.14	-0.10	0.05	0.04	0.34
SS loadings	3.53	2.79	1.9	1.55	1.39	1.28	
Proportion Var	0.15	0.12	0.08	0.06	0.06	0.05	
Cumulative Var	0.15	0.26	0.34	0.41	0.46	0.52	
Cum. factor Var	0.28	0.51	0.66	0.79	0.9	1	
Kayser-Meyer-Olkin MSA	0.82						

Source: Innovation Data (2018), n = 4811.

Six factors are shown to be constructs of the latent behaviour of firms, choices that firms make which are relevant for their innovative activities and are taken at the same time. These latent constructs can be considered operational strategies. In Table 6.1, the factors are shown for each variable, which can be given interpretable names as well. I will describe all six factors in turn.

MR1 describes choices in the open innovation paradigm, firms relying on cooperation relationships with suppliers, universities, competitors and clients, internally and with consultants. These are formal cooperations and partnerships in some activities.

MR4 describes choices in a science-based strategy. Factors load on relationships with universities, both formal and informal. Firms rely on internal and external R&D, and acquisition of knowledge as inputs for innovative activities. They also use consultants. This is the only strategy which relies on formal methods of appropriation, such as patents, industrial designs and industrial models.

MR2 describes a marketing-oriented strategy. Firms rely on marketing as the most important input. They have a high innovation intensity with innovations that are new only to the firm. These choices coincide with goals that aim to capture new markets geographically and widen the portfolio of products and services. Smaller loadings are on formal and informal relationships with clients and, similarly, with methods for appropriation, both trademarks and formal.

MR5 describes a copying strategy. The most important inputs are informal relationships on the market, especially with competitors. Firms rely on information received from other sources, but these choices are not binding. There is some indication of forming formal partnerships with competitors and even less with other partners.

MR3 is a strategy reliant on suppliers. Firms use suppliers to create innovative processes. The relevant inputs are training of employee skills and acquisition of machinery.

MR6 is an internal strategy. Firms rely heavily on internal sources and work within the group. This strategy depends on subsidiary relationships.

These 6 factors are used for the second step of the analysis — k-means clustering. Solutions between 3 and 6 clusters were compared, and 5 was ultimately chosen. Solutions with 6 clusters started creating very small clusters which did not have very distinct diversity to justify the estimation.

The fewer clusters there are, the more variation is needed in its strategic behaviour for the firm to be shifted into a new group. This means that if fewer clusters are created, the level of change a firm needs to make in its innovative behaviour is greater and the relative number of shifts should be lower. If possible, fewer clusters would make the threshold lower, which would be considered a strategic change.

Using factors as a baseline for clustering yields possibilities that some clusters will rely on two coinciding factors at the same time. However, most firms rely heavily on a single strategy. A cross-table between clusters and factors is in Table 6.2. These clusters will be interpreted as patterns of innovation. The numbers in the table are means of factor scores, and the underlying distributions are presented in Appendix VI.

Table 6.2: Cross-table of clustering solutions with factor loadings

Pattern of innovation		Factor scores MR1 Open	MR4 Science	MR2 Marketing	MR5 Copying	MR3 Suppliers	MR6 Internal
Open innovation	1	2.25	0.36	0.19	0.67	0.34	0.38
Science based	2	0.47	2.73	0.21	−0.29	0.12	0.13
Market oriented	3	−0.59	−0.05	0.56	0.33	−0.24	−0.34
Internal strategy	4	−0.05	−0.39	0.21	−0.52	−0.07	1.51
Supplier based	5	−0.33	−0.46	−0.86	−0.35	0.14	−0.5

Source: Innovation Data (2018), n = 4811.

There are some strategies which create more distinct patterns of innovations than others. For example, open innovation and science based strategies are more separate from other strategies. The internal pattern of innovation is also representative of a very specific attitude. Market oriented and supplier based patterns of innovations are more alike than others. They mostly are distinct based on two factor scores, either marketing or suppliers.

The visual distribution seen in Appendix VI shows how these patterns of innovations coincide. For example, for MR3, the supplier based strategy, most patterns of innovations actually have fairly similar distributions. All firms rely on suppliers to some extent.

For some strategies, such as MR2, the marketing oriented strategy, firms are divided. Firms in the supplier based pattern of innovation rely less on this strategy than all other patterns of innovations.

Firm specific descriptives are in Table 6.3. The two biggest patterns of innovations are the market oriented and supplier based categories. They account for nearly two-thirds of all observations. The smallest category is science based firms. Open innovation and internal strategies are roughly the same size.

The factoring solutions did not include whether the firm was foreign-owned or part of a group. However, from the behaviour alone, it was possible to induce an internal strategy pattern of innovation, out of which 99% of firms are part of a group. This is a good indication that the clustering solution can create believable constructs.

Table 6.3: Firm characteristics in patterns of innovations

Pattern of innovation	Obs	Firms	Workers	Foreign owned	Part of group	Tangible assets	Intangible assets
Open innovation	618	443	183.46	0.4	0.67	9 041 676	396 569
Science based	300	200	248.26	0.32	0.57	12 548 251	656 339
Market oriented	1699	1180	74.55	0.27	0.43	2 058 475	90 410
Internal strategy	699	503	128.75	0.6	0.99	6 155 868	138 349
Supplier based	1495	1043	72.61	0.23	0.41	2 845 135	86 079

Source: Innovation Data (2018), n = 4811.

There are some size differences between patterns of innovations. Bigger firms are more likely to be science based or open innovation, smaller firms market oriented or supplier based. The latter categories were characterised by lack of partnerships. Perhaps smaller firms lack capabilities to establish partnerships and have to rely on more informal relationships.

Table 6.3 also highlights fixed assets on balance for these firms. Mean values for tangible and intangible assets are visible and correlate with firm size based on employees. There are small differences between market oriented and supplier based firms. The ratio between tangible and intangible assets is larger in supplier based firms, more towards tangible assets, and in market oriented firms, towards intangible. This aligns with strategies as well, as market oriented firms are more likely to use trademarks and marketing as an input to innovative activities.

The characteristics shown in Table 6.3 are one indication that smaller and bigger firms also have different decision making processes. The underlying variables which were used to create constructs of innovative behaviour did not include any variables that could be directly linked with firm size or industry, such as number of workers or revenue. Because firms are not able to change their size or industry quickly, this would create patterns of innovations based on fixed characteristics. Firm strategic choices can change more quickly. If firms position changes from one pattern of innovation to another in subsequent periods, it is based solely on strategic choices.

The ratio between observations and firms shows how stable the clustering solution to estimate patterns of innovation is. Firms have multiple observations in the dataset. A perfectly stable firm would be counted several times within one pattern of innovation. If the ratio between observations is close to one, it would mean that every firm would be within a pattern of innovation only once, a relatively unstable position and a strategy that is not persistent.

Table 6.4: Innovation outputs in patterns of innovation. Share of firms with output, in percentages

	Type of innovation output:			
	Product	Process	Organisational	Marketing
Open innovation	80	82	74	64
Science based	82	74	60	53
Market oriented	86	62	49	52
Internal strategy	70	77	55	40
Supplier based	23	80	37	27

Source: Innovation Data (2018), n = 4811.

Firms within different patterns of innovations also contrast in their innovative output patterns. Table 6.4 presents the main innovation outputs within all patterns of innovations. Other characteristics based on decisions are in Appendix VII. I will briefly characterise all patterns of innovations.

Open innovation firms are most innovative of all patterns of innovations. They rely heavily on partnerships and external knowledge and consider sources outside of the firm to be important to their innovative activities. They rely less on universities and public research institutes and more on other types of sources, such as suppliers, clients, competitors, consultants, conferences and so forth. Open innovation firms fund inputs for innovative activities relatively more than other patterns of innovations. However, R&D is not their main focus. Open innovation firms aim to increase quality in production, increase productivity and flexibility, widen their portfolio and find new markets. Open innovation firms can be considered active in their strategy with focus on different aspects and partnerships at the same time.

Science based firms rely heavily on universities and public research institutes and do the most in-house and outsourced R&D relative to all other patterns of innovations. They have relatively low levels of partnerships with competitors. The most important goals for science based firms are quality increases, new markets and portfolio widening. At the same time, science based firms have the highest values for use of different appropriation methods. They have the only patterns of innovation which rely on patents, industrial models and industrial designs. They also have the highest share of trademarks registered. Science based firms rely most on technological knowledge, since their innovative output is focused more on products than processes. This group is the smallest in the sample.

Market oriented firms have the most product innovations and fewer process innovations. Their strategy relies on outside sources of knowledge, such as competitors, clients, suppliers and conferences, and less so with universities. However, they have very little formal partnerships. If so, these are only with clients and suppliers. At the same time, their goals are to widen their portfolios of products and services, capture new markets and increase quality. The only appropriation methods they rely on are trademarks. Market oriented firms rely on external informal knowledge. They have the highest share of relying on marketing funding as an input to innovative activities. Other inputs lie in the relative middle, between extremes. The market oriented pattern of innovation is the largest in this sample.

Internal strategy pattern of innovation is mainly based on within group relationships. Firms in this group have both product and process innovations as outputs, while the focus is on the latter. Their most important sources are internal or within group, followed by suppliers. Virtually all firms are characterised by formal relationships within the group as well. Around one quarter also have partnerships with clients and suppliers. The most important inputs are machinery and worker training. Acquisition of knowledge, internal R&D and marketing are also relevant in this group. The main focus is on quality increases, followed by portfolio widening and flexibility in production.

Supplier based pattern of innovation is the least innovative. These firms are focused on process innovations, while few also have product innovations. They have virtually no formal partnerships with anyone except suppliers, and the most important source for innovative activities is also suppliers. The mean values for other groups are lowest among patterns of innovations identified here. Their most important goal is quality increase, followed by productivity increase and flexibility in production. Most supplier based firms rely on acquisition of machinery as an input to innovative activities. The second most important input is worker training. Supplier based pattern of innovation is the second biggest in the sample.

Firms that have multiple observations in the dataset can belong to any of these patterns of innovations based solely on their choices and actions while doing innovative activities.

Since patterns of innovations are categorical values, I will use plots that describe state sequences to visualise firm behaviour. These are not very known in economics, but more in other sociological fields which deal with discrete state analysis.

The dataset includes 3502 firms with 9155 observations. This is an unbalanced dataset, where a lot of firms have few observations, some only one. Patterns are described in Appendix II. However, there is a smaller balanced dataset within this sample. This consists of 654 firms, all of which have been surveyed in every CIS included here. Altogether these 3270 observations account for 35% of the total sample.

I believe that the plots are more understandable for the reader when the smaller balanced dataset is used. Therefore, I will show the plots for the smaller balanced dataset in the main text and the full sample plots are in the appendices. When contrasted, they seem to indicate the same results which are also confirmed with state transition matrices later on.

All firms which were included in the CIS but indicated that they were not innovative were included in the analysis. They received a *not innovative* category, since they did not have an innovation strategy. The CIS surveys whether firms had a failed or continuing strategy, but these firms indicated that this was not the case. This allows us to observe also the persistence of innovative behaviour.

Figure 6.2 in the text and in Appendix VIII show state distributions over time. The state distributions indicate if major structural shifts occurred, such as firms taking up different behaviours. The not innovative category becomes larger in later years. The only shift visible is that market oriented and supplier based patterns of innovation become smaller and not innovative becomes larger. The rest remain relatively the same over the period.

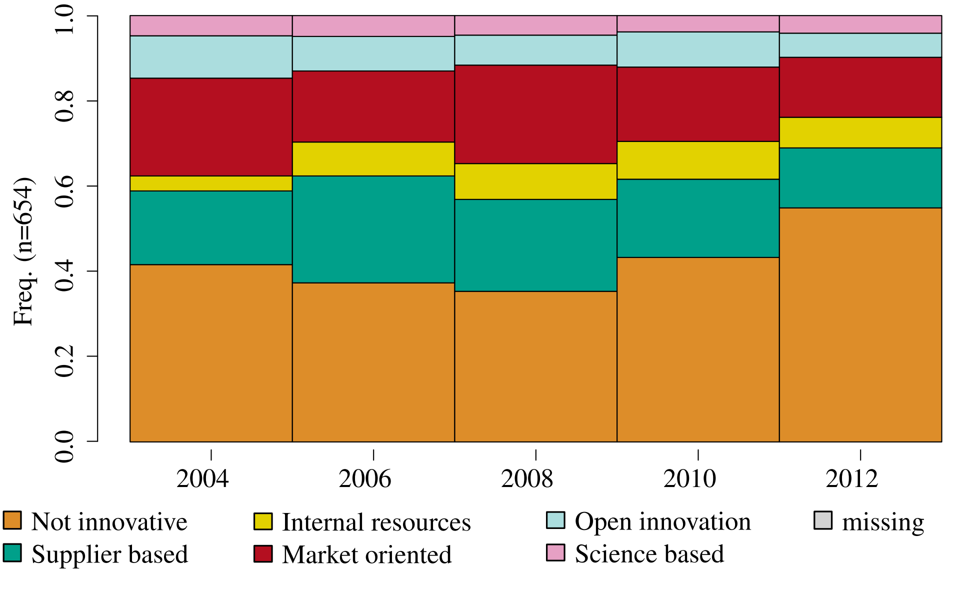

Figure 6.2: Patterns of innovation states distribution plot over time. n = 3270. Source: Innovation Data (2018)

Figure 6.3 in the text and in Appendix IX show the distribution of states for every firm. This plot draws a single line for every firm that is included and plots its state

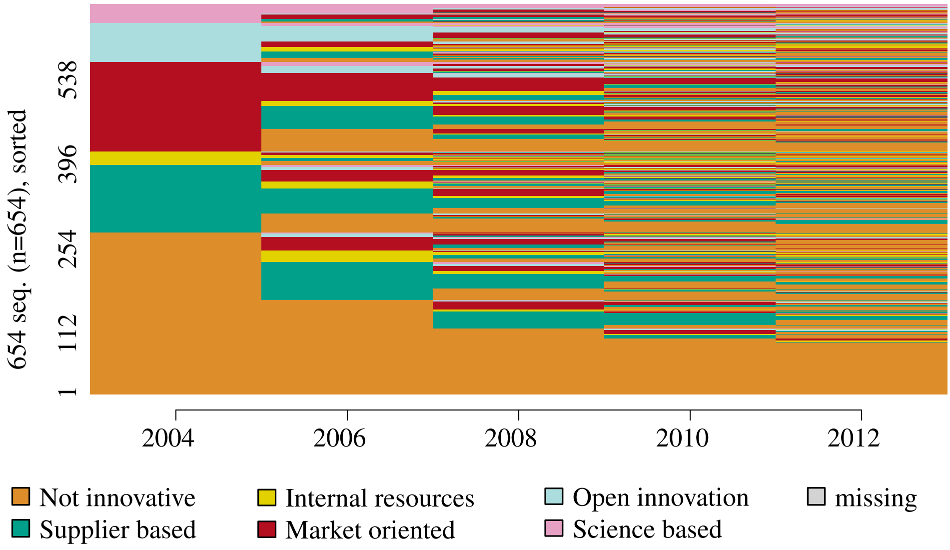

Figure 6.3: Patterns of innovation state sequence plot over time. n = 3270 (obs.); n = 654 (firms).
Source: Innovation Data (2018)

sequences in color. For example, the first line in Figure 6.3 is a firm that started as a science based firm in 2004 and remained so until 2012. The plot is sorted from period one for easier visualisation. These figures allow us to visualise the path for every firm.

Figure 6.2 and Appendix IX show that firms are not very stable in their patterns of innovation. There are very few firms which have managed to stay in the same pattern of innovation for five periods in a row. The majority of these cases belong to the not innovative category. This implies that the persistence of being not innovative is stronger than belonging to any single pattern of innovation. However, firms are free to change between patterns of innovations as well.

Overall statistics about shifts between patterns of innovation are in Table 6.5. The last column, where firms have participated 5 times, is the exact same smaller balanced panel visualised in Figures 6.2 and 6.3.

From visualisations in Figure 6.3 and in Appendix IX and Table 6.5, it is evident that firms change their behaviour quite often. For example, half of firms which have participated twice in the CIS belong to different patterns of innovations the second time. For firms with three and more observations in the dataset, the probability to remain in only one pattern of innovation is the smallest. Therefore, there are considerable dynamic effects in firm innovative behaviour, constant changes that are big enough that they are measurable with strategies constructed here.

Table 6.5: Cross-table of CIS participation and pattern of innovation affiliation

Unique patterns of innovations per firm	CIS participations 1	2	3	4	5
1	1193	379	181	81	100
2		312	272	183	274
3			93	130	211
4				24	66
5					3

Source: Innovation Data (2018), n = 9155.

The largest variance can be seen for three firms which have belonged to five different patterns of innovations over the period, a relatively large shift in behaviour during ten years. These three firms did not have a dynamic that could be explained with simple logic, starting from supplier based and ending with scientific capabilities.

Table 6.6: State transition matrix for all firms for all periods, in percentages

From:	To: Not innovative	Supplier based	Internal strategy	Market oriented	Open innovation	Science based
Not innovative	74.0	12.7	3.6	7.3	1.9	0.6
Supplier based	35.1	34.8	6.8	16.8	4.5	2.2
Internal strategy	25.5	14.1	34.5	16.2	7.6	2.1
Market oriented	26.0	20.1	7.9	34.7	7.4	4.1
Open innovation	11.6	14.3	13.5	21.9	31.4	7.4
Science based	8.0	8.5	3.2	25.0	11.7	43.6

Source: Innovation Data (2018), n = 9155.

In Table 6.6, there is a state transition matrix for all observations. This is calculated for every observation pair, the transition probability to shift between states. The diagonal is the measure of stability, the probability to remain in the same state.

The highest probability is for not innovative firms to remain not innovative. The second highest probability is for science based firms to remain science based. For other categories, the probability to remain the same is around 35%. For supplier based firms, there is slightly higher probability to be not innovative in the following period than remain in the same category. This is the only category where change from the original state is less probable than shifting.

The first column in Table 6.6 is basically probabilities for firms to become not innovative in subsequent periods. It is clear that the probability is low for science based firms and firms with open innovation strategies. For internal strategy and market oriented firms, the probability to be not innovative in the next period is around 25%. For supplier based firms, it is 35%.

The lowest probabilities are in the last column, the probability to become a science based firm. If the firm was not innovative in the previous period, there is less than 1% probability that they opted for a science based strategy in the next. This is an indication that capabilities are difficult to build. For other patterns of innovation, the probabilities are less than 10% to become science based in the next period.

There is a full state transition matrix in Appendix X, where transition rates are calculated between every period with missing values included. Similar conclusions can be drawn from this transition matrix: the probability to become not innovative increases over time. This could be deduced from descriptive statistics as well, which show a downward sloping trend for innovativeness.

The highest probability to not be included in the next CIS is for market oriented firms. It is not known whether it is because their business fails or because most firms are market oriented and are substitutable in data gathering.

The relative stability of patterns of innovation gets smaller in every subsequent wave. Firms are changing their strategies more often than in the beginning of the period. The probability of shifting between different innovation strategies is high, meaning firms change their attitudes towards innovative behaviour often. They change partners for upgrading knowledge bases and cooperation networks often. This result is similar to findings from Switzerland (Hollenstein, 2018), where the high rate of transition is due to the pressures in a highly advanced economy to increase innovation intensity. However, Estonian firms are not known to be at the forefront of innovative activity, politely called moderate innovators in the EU Innovation Scoreboard. There is a need for better understanding of the determinants of shifting between patterns of innovation.

A variance based estimation of firm-level patterns of innovations gives robust results which are similar to cross-sectional studies done before. I have tested this model with Pearson and polychoric correlation matrices as a baseline. I used these as input for EFA and PCA and clustered the scores. Depending on the input variables, it is possible to create patterns of innovation that are more skewed towards innovation, cooperation or fiscal attributes. These results remained the same when all the variables used in the descriptive tables were included or other combinations of them. In all tests, the overall structure across different years remained relatively stable.

The patterns of innovation created here remain as a baseline for Chapter 8, where one possible mechanism to induce dynamics is investigated. The next chapter establishes the relationship between public sector support and innovativeness. These patterns of innovations are stored for later estimations without changes.

7. PUBLIC SECTOR SUPPORT AND FIRM INNOVATION OUTPUTS

The structure of this section is as follows. First, I will explain the aim of this chapter, the research questions and objectives. Second, I will describe where it fits in the theory provided in Chapters 2 and 3. Third, I explain the method to reach the objectives. Fourth, I estimate the results. Fifth, I interpret the results. Sixth, I discuss how it relates to the rest of the thesis.

7.1. Subcategories of innovative outputs

The aim of this chapter is to investigate if policy instruments are related to innovative activities. If the main aim of this thesis is to understand the possible effect that policy instruments can have on the dynamics of firm innovation strategies, then it must be established beforehand whether policy instruments are related to innovation at all. To achieve this aim, I estimate the relationship between firm innovation outputs and policy instruments.

At the end of Chapter 2, the innovation process of the firm is graphed. Policy instruments can affect multiple parts of this process within the single firm, as shown in Chapter 3. In this estimation, it is only possible to observe if there are significant correlations between innovation outputs and policy instruments. Innovation outputs are surveyed in the CIS. In Figures 5.5 and 5.6, innovation outputs are shown in broad categories.

The distinction of innovation outputs is even more specific in the CIS. In Table 7.1, technological and non-technological innovation outputs are shown. The main categories, technological and non-technological, are divided into four subcategories: product, process, marketing and organisational innovations. Product and process innovations also have subcategories.

The distinction and definitions are based on the Oslo Manual (OECD, 2005), which is the theoretical foundation for the CIS. Chapter 4.1 provides background on the CIS, how the data is gathered, what type of questions are involved and the possible setbacks. Here, I will provide brief descriptions of these categories based on how they are defined in the Oslo Manual (OECD, 2005)[1].

[1] The main types of innovation are defined in Chapter 3 and citations therein, which I recommend to all interested readers if they wish to understand how innovation measurement is done in practice, and how they are defined in the CIS.

Table 7.1: Technological and non-technological innovation outputs with subcategories, by year, in shares of survey population

CIS	2004	2006	2008	2010	2012
Firms in survey	1747	1924	2026	1735	1723
Technological	0.52	0.56	0.56	0.54	0.45
Product innovations	0.39	0.37	0.33	0.30	0.25
New products	0.29	0.27	0.23	0.21	0.18
New services	0.17	0.18	0.17	0.14	0.11
Process innovations	0.37	0.44	0.44	0.38	0.28
New process	0.25	0.33	0.35	0.28	0.20
New distribution	0.09	0.07	0.12	0.10	0.06
New support system	0.22	0.21	0.21	0.19	0.14
Non-technological	0.51	0.54	0.40	0.40	0.34
Marketing	0.26	0.34	0.27	0.28	0.24
Organisational	0.44	0.46	0.29	0.27	0.23

Source: Innovation Data (2018), n = 9155.

Product innovations are goods or services which are new or significantly improved. Product innovations can include improvements in technical specifications, materials, components, software, ease of use or other functional characteristics. They can be combinations of existing knowledge or completely new knowledge. An example of a combination of existing knowledge is the iPhone, where existing technologies were combined in a way to create a new innovative product. An example of completely new technologies creating completely new products is the first digital cameras.

New services can include new functions, improvements in means of provision, some other characteristic improvements, or completely new services. An example of a new service is 'click and collect' package automation service, where customers can pick up their packages from various locations instead of having couriers reach their location. An example of an improvement is new functions and ease of use in e-services such as banking, e-shopping, etc.

When Pavitt's taxonomy (1984) (see Chapter 2.1) considers relationships between firms on how innovations are produced, new products and services can be a simple example. An example of 'click and collect' automated package collection robots was given as a new service. These machines are currently very popular in Estonia. This is a new service to postal companies in how they deliver packages and interact with customers. They offer significant improvements in comfort for some customers, not mentioning a reduction in the cost and time it takes to reach customers, if they do not have to visit everyone's location. These machines are also product innovations for the companies that invented them and are supplying the hardware. It includes process innovations for postal companies in how they have to manage logistics, package tracking, customer relations and so forth. Delivering a new service to customers can be a combined effort, where innovations take place in several companies which are all suppliers, providers, inventors, supply chain managers and so on. In Pavitt's taxonomy, the postal company can be a supplier based innovative firm. Machine providers are either science based, when they invest heavily in R&D and invent in broad categories, or specialised suppliers that make tailored machines.

Process innovations are implementations of new or significantly improved production or delivery methods. Improvements include changes in techniques, software and equipment.

Subcategories include new processes for production, new or improved distribution systems or new support systems. New production processes involve techniques, equipment, machinery and software used to produce goods or services, for example, new automated production lines, such as automated filling machines in breweries. New distribution systems include logistics and components that deal with logistics or delivery. Relevant improvements can be in similar aspects as in production, new machinery, new techniques or software. The latter category, support systems, includes activities such as purchasing, accounting, maintenance or computing.

Non-technological innovations are related to marketing and organisational innovations.

Marketing innovations are new or significantly improved marketing methods, significant changes in packaging or design, placement, production or pricing. The latter four are known as the marketing mix or the Four P's in marketing literature. Marketing innovations should be distinguishable from a firm's normal marketing instruments, either as new concepts or a new strategy. For example, regular end-of-season sales are not marketing innovations.

Organisational innovations are related to new business practices, workplace organisation or external relations. It should be a result of strategic decisions by management, not serendipitous. The general idea is that improvements are related to increasing firm productivity by cost savings or worker satisfaction, gaining access to new knowledge and new types of relationships.

The Oslo Manual (OECD, 2005) has examples for subcategories for both marketing and organisational innovations. However, these have been changed and clarified several times during the five CIS waves that are in the dataset used in this thesis. For this reason, subcategories for these innovation types are not used in the analysis. There might be issues with comparability over the whole period.

7.2. Generalised linear mixed model

The second estimation in this thesis estimates the relationship between innovation outputs and public sector support. A taxonomy of public sector subsidies available to the firm developed in Chapter 3 is used to distinguish between possible inputs from the public for innovative activities. The novelty in this estimation is the possibility to look at the relationship between different types of policy instruments at a fine level and compare it between possible innovation outputs.

Innovation outputs are measured via output indicators of innovative activities such as product and process innovations with subcategories. The description of the data and available outputs is in Chapter 4.1. All output indicators are binary data for the firm.

The model is specified as a random effects logit model. This is also known as a generalised linear mixed model (GLMM) with a binomial link and both fixed and random effects. The model is specified as a GLMM with random intercepts.

GLMM specifies fixed effects for controls, such as time and industry. Random intercepts are estimated for every firm.

The model is specified as:

$$P\left(y_{ij}\right) = \frac{\exp\left(\alpha + \sum_{k=1}^{K} \beta_k X_{ijk} + u_j\right)}{1 + \exp\left(\alpha + \sum_{k=1}^{K} \beta_k X_{ijk} + u_j\right)} \tag{7.1}$$

where:

ij = ith observation for the jth firm
K = number of independent variables (fixed effects); 21 for the full model
X = independent variables
α = intercepts for whole model
β = coefficients
u_j = intercept for every firm

The second most common alternative model for estimating logit models in a panel setting is the fixed effects model, which is not feasible with this data. I will explain this based on the sample used in this thesis. If there is a large number of firms, but not many observations over time for every firm, there is no variation in the outcome within a single firm. The advantage of fixed effects is that the model compares the single firm against itself over time, meaning there is no need for some of the control variables. The controls are unobserved characteristics that do not change over time within the firm, but they are very different when compared between firms, such as the entrepeneurial culture near the firm's location or the strength of the financial system in a region. These are hard to control for, but they remain relatively unchanged for the firm during the estimation. The weakness of fixed effects is that there should also be some sort of variation in the outcome. If the dataset is very unbalanced, there is just not enough variation in the outcome for most firms. In the sample here, the firms are either innovative or not during the whole period. Therefore, a random effects logit model specification is more suitable in this case. For firms without variation in outcomes, mean variation is used for estimating coefficients.

Since firms cannot be compared against themselves over time,the random effects model should include control variables for firms. Table 7.2 highlights the descriptive statistics for control variables. The full model specifies controls for firm size, firm age, exporting status, foreign ownership, time and industry.

Table 7.2: Control variables in model, share of sample or mean, by year

Variable	2004	2006	2008	2010	2012
Observations	1 747	1924	2 026	1 735	1 723
Foreign owned firms	0.28	0.29	0.25	0.28	0.26
Exporting firms	0.72	0.72	0.72	0.78	0.79
Workers (mean) (log in model)	86.07	83.38	79.96	72.26	70.38
Age (mean)	9.16	10.26	11.47	12.99	14.02
Science based	0.09	0.09	0.07	0.08	0.09
Scale-information intensive	0.16	0.17	0.19	0.19	0.19
Specialised suppliers	0.12	0.14	0.15	0.12	0.14
Supporting infrastructure services	0.08	0.07	0.08	0.09	0.08
Supplier dominated	0.55	0.52	0.51	0.52	0.49

Source: Innovation Data (2018)

Industry control is based on technological regimes, which are estimated using NACE data. Technological regimes imply innovating activity characteristics which are relevant or special for these industries. They are based on sources of technological opportunity, the appropriability conditions for rents, the cumulativeness of innovations and the complexity of the knowledge base (Bogliacino and Pianta, 2016; Castellacci, 2008; Pavitt, 1984). A detailed description of technological regimes is in Chapter 2.1. A NACE classification used in the estimation has been reported in Bogliacino and Pianta (2016).

For calculation references, see Bates et al. (2015).

7.3. Endogeneity in regression models and self-selection

We can observe in the Estonian data that innovative firms have higher rates of being beneficiaries in innovation policy instruments (see Chapter 4.2). However, simple conclusions about the impact of these instruments cannot be inferred from this data. Evaluating public support policy programs is notoriously difficult. "*Evaluating such programs is an exercise in counterfactual analysis; neither supported firms, nor firms not applying for funding can be treated as a random sample*" (Grilli and Murtinu, 2011, p. 3). This non-randomness creates an endogeneity problem. It is generally referred to as a selection bias.

Firms have observed and unobserved characteristics. Observed attributes are usually size, age, location, revenue, etc. These may imply something about the firm as proxies or describe some of their characteristics in a straight-forward manner. Unobserved attributes are trickier, since, well, they cannot be or are very difficult to observe. Some examples are work-ethics and culture in the firm, management capabilities and ambition, quality of ideas and vision for the future, and so forth. It is easy to see that these matter a lot for the future success of the firm as well.

Selection bias takes place when firms in the treated group, i.e. who received public support, and the untreated group, i.e. control group, are different in the unobserved attributes. Two simple examples explain from where this selection bias may arise. First, firms self-select into these programs. Therefore, there is something innately different in the firms or their projects than their peers that do not enter these programs. Second, public agencies also tend to cherry-pick projects which they believe have a higher chance of succeeding. This can be quasi-random, whereby all eligible firms are drawn from a lottery, but it is rarely so. Most likely, public agencies look at the project itself and assess it on some level, even if this assessment is purely subjective. Therefore, this characteristic of beneficiaries is also very hard to observe and quantify.

If this characteristic of the firm that creates the selection bias is not observed and it affects both the probability of becoming a beneficiary of policy support instruments and the likelyhood of being more innovative or succesful, it creates an empirical problem for estimation (Heckman et al., 1998). Simple regression models are biased in this case. For example, Ordinary Least Squares will underestimate standard errors with selection bias and, therefore, overestimate statistical significance (Heckman, 1979).

In his Nobel lecture, James Heckman referred to this estimation problem with regards to evaluating the effects of public programs as the *treatment effect problem* (Heckman, 2001). In essence, the question is "*what is the effect of a program in place on participants and nonparticipants compared to no program at all or some alternative program?*" (Heckman, 2001, p. 677). It also means that plausible counterfactuals have to be used when treatment effects are estimated. There are many advances in estimation and identification techniques that try to minimise potential selection bias in policy support programs (Brown et al., 1995; David et al., 2000; Klette et al., 2000; Zúñiga-Vicente et al., 2014).

I referred to these techniques as both estimation and identification techniques because some of them do not rely on better econometric approaches but rather on a better study design that incorporates a good method for creating a control group from the beginning, for example, randomised controlled trials (RCT). In the Maryland Scientific Methods Scale (SMS), there are five levels with increasing complexity and accuracy (Petticrew and Roberts, 2008; Sherman et al., 1998; Welsh and Farrington, 2007).

Most of our current academic discourse starts from level three with methods such as Difference-in-Difference (DiD) estimators, General Linear Mixed Models (GLMM) (which is also used in Chapter 7), matching procedures with Propensity Score Matching (PSM) being most popular, and Heckman Selection Models (Cerulli, 2010; Imbens and Wooldridge, 2009)[2]. These methods rely on comparing treated groups with counterfactuals with selection bias still in the data generation process. However, regression or matching methods on observed characteristics are used to adjust for these differences, so that firms are compared to their most similar peers. Therefore, some unobserved differences will probably remain (Czarnitzki and Lopes-Bento, 2013b, 2014).

Level four methods are more robust techniques, most popular being Instrument Variable (IV) models or Regression Discontinuity Design (RD), both of which use quasi-randomness to mimick experimental design. IV models are estimated in a way that proper instruments are identified which only affect the independent variable (in this case, the probability of obtaining the public support instrument), but they have no effect on the outcome (firm performance) (Imbens and Angrist, 1994). Unfortunately, good instruments are very hard to come by. RD models are estimated when there is a ranking in the selection process (Imbens and Lemieux, 2008). Samples are constructed in a way that only firms which are barely above the threshold are compared to a control group just below the threshold. The general idea is that these firms are so similar to each other, that receiving public support was basically just pure luck, i.e. a random process.

The gold standard on level five would be RCT design. A large enough sample permits treatment to be allocated randomly to participants, thereby removing selection bias, since both groups end up being similar in observed and unobserved characteristics (Duflo et al., 2006; Roper, 2018). RCT design has to be created *ex ante* in the data generation process (Bakhshi et al., 2015; Burtless, 1995). There

[2] Some examples of recent papers for all of these methods can be found in Zúñiga-Vicente et al. (2014)

is a movement to promote more RCT based experimental policy for better understanding of the effects of public policy, such as the Innovation Growth Lab and What Works centre in the UK[3], the International Initiative for Impact Evaluation, or the Abdul Latif Jameel Poverty Action Lab (J-PAL). However, there are several features that make the use of RCTs difficult in business support programs, and they might never reach to the same popularity as in medical science (Dalziel, 2018).

The methods used in this thesis would be qualified on level three of the Maryland SMS scale. Firms are observed over several periods for before-and-after analysis, and observable controls are used in modelling. Quasi-random and pure randomly generated processes are not used in this thesis.

Since the final chapters of the thesis are more concerned with shifts between different states, Markov-Chain models are used for estimation. These models are not very common in public support analysis and are rarely, if at all, mentioned in surveys of methods and recent results cited here. Still, they provide valuable insight in the context where there is a large number of choices for firms and possibilities to change their strategies over time.

Most methods in surveys here deal with binary contexts whereby selection processes are modelled for very specific instruments[4]. In this thesis, a much larger variance is included in the models which restricts some of the possibilities. Therefore, it is safe to say that some overestimation of statistical significance in regression models is highly likely due to selection bias into different business support instruments.

7.4. Estimation of relationship between policy instruments and innovativeness

The main results for technological innovations are in Table 7.3 and for non-technological innovations in Table 7.4. I will introduce the model results for technological innovations and subgroups first, and then for non-technological innovations and subgroups.

These models in Tables 7.3 and 7.4 are presented with subgroups. Estimates cannot be compared between models, as in comparing the size of coefficients for investment instruments between new products and new process models. However, estimates can be compared within the model, such as comparing investment instruments with consulting instruments in the new product innovation model. This

[3] Innovation Growth Lab in the UK also hosts a database of recent RCT based trials worldwide

[4] A good example of a Heckman selection model for multiple grant possibility is in Hottenrott et al. (2017).

refers only to coefficient size. The significance of the coefficient suggests that a positive or negative relationship is not random.

Estimates for technological innovations suggest that investment, innovation and R&D, marketing and export promotion, and training and skills development instruments are positively linked with technological innovation outputs. Consulting, financial guarantees, mixed support and others are not.

Within product innovations and its subgroups, new products and new services, some aspects are highlighted. For example, investments, training and skill development, and marketing instruments are positively related with product innovations. However, within this category, they are only positively related with new products and not with new services. This suggests that firms with innovative activities mainly related to the creation or improvement of services are not more likely to be beneficiaries in these instruments.

Investment schemes usually consist of buying new machinery and other equipment, which can provide some explanation to the link with new products and not with new services. With marketing and export promotion instruments, it is difficult to ascertain. Firms with new products and services should both be equally likely beneficiaries of these instruments. Similarly, training and skills development instruments are often dealing with soft skills such as marketing, promotion and management, which are not unique to either products or services.

Mixed support is a relatively rare instrument in this dataset, and it is positively correlated with only new products in the product innovation categories. Most firms in this instrument are part of early phase support programs, which might explain the link with new products.

Other instruments, which are a combination of collaboration programs and direct subsidies, are positively correlated with only new services in the product innovation category. However, these instruments are very different from each other and very rare. It is difficult to ascertain the exact relationship between the innovation output and instruments.

Process innovations and its subgroups, new processes, new distribution systems and new support systems, show similarly that policy instruments are not uniformly related with firms. Innovation and R&D instruments are not related with any type of process innovations at all. This suggests that firms that participate in these types of instruments are more focused on developing novel products or services.

Investment instruments are positively related to new processes and new support systems but not with new distribution systems. Investments are mostly acquisition of new machinery and equipment, which should almost always yield process innovations. The lack of effect on new distribution systems suggests that firms are not seeking extra funding to create these innovations.

Marketing and export promotion instruments are positively correlated with all types of process innovations. This suggests that firms actively seeking new markets or new methods for marketing their products are also actively developing internal processes. The direction of causality is not established with this model.

Training and skills development instruments are positively correlated with new processes and new support systems but not with new distribution systems. Training and skills development instruments are mostly soft instruments, so there should not be any distinction here.

Estimation coefficient sizes in a random effects model, where dependent and independent variables are both binary, are log odds. Log odds are not very intuitive to interpret. They can be transformed to probabilities, but it is not really necessary. The coefficient estimate is not so exact that it could be interpreted as valid for every situation. Log odds relate to probabilities in a s-curve relationship: log odds 0 is 50 percent probability of the situation; above that is higher and negative is less. A simple takeaway is that if the log odds (coefficient estimate) is positive, there is a positive relationship and, if negative, vice versa.

It is interesting to note that coefficient estimates indicate that firms participating in marketing and export promotion instruments have a higher probability to have product innovations than firms participating in investment instruments. A converse effect is seen for process innovations. If it would be clear that causality is from instruments to innovation outputs, it would suggest that marketing instruments are much more effective for creating product innovations, not to mention the massive savings it could produce. However, this is a good example that causality can run both ways in this type of regression model.

Estimates for non-technological innovations suggests that innovation and R&D, marketing and export promotion and training and skill development instruments are positively related with non-technological innovation outputs. Other instrument types are not. Since non-technological innovation subcategories were changed several times between the five CIS waves used in this analysis, only wider categories for organisational and marketing innovations can be compared.

Innovation and R&D instruments, marketing instruments, training and skill development instruments and mixed support instruments are positively correlated with marketing innovations. Marketing innovations suggests that firms develop new marketing strategies or significantly improve their design or packaging. A direct relationship could be assumed from marketing and export promotion instruments. For other instrument types, the relationship is less clear. Training and skill development instruments are often for soft skills such as marketing, promotion and management, which could improve a firm's choice of strategy. Mixed support instruments are mostly early phase development instruments meant for new ventures, suggesting that young firms have to create new marketing strategies at an early stage. However, firms participating in innovation and R&D instruments could have an indirect link. They are also positively correlated with new products, which might be linked with marketing innovations.

Training and skills development instruments are the only ones that positively correlate with firms developing organisational innovations. These instruments are mainly teaching new skills, managerial among them, which could help create organisational innovations.

Policy instruments have less positive and significant relationships with non-technological innovations than with technological innovations. There are no significant negative relationships for any type of policy instrument among these 11 models.

In most cases, positive and significant relationships are logical, suggesting that firms participating in certain instruments are also innovative in similar outputs. Some instruments, such as consulting, labour support and financial guarantees are not related with any type of innovation outputs at all. These instruments are either not supporting any innovative activities, such as labour support, or non-innovative firms self-select into these instruments. As mentioned before, this type of model does not give any indication of causality.

Control variables for these models are mostly significant, and coefficients are logical. For example, as explained in Chapter 2, exporting firms and foreign firms tend to be more innovative. Both Schumpeter Mark I and Mark II patterns of innovation were introduced in Chapter 2.1. Mark I suggests that young, small firms are more innovative, and Mark II suggests that older, larger, more corporation type firms are more innovative. Control variables in models estimated here suggest that, for Estonian firms, larger firms are more innovative on average. However, firm age is negative and significant in all models, suggesting that older firms are not more innovative.

Controls for technological regimes are compared to their base values for the scale and information intensive technological regime. The values for control variables are logical and aligned with concepts described in Chapter 2.1. Science based firms are more innovative than scale and information intensive firms. Supplier based and specialised suppliers are less innovative. For supplier based firms, it is to be expected that they are relatively less innovative than other categories. However, specialised suppliers should not be less innovative. This might be a speciality of Estonian firms, which could be investigated further in other research. Finally, there is a group of firms supporting infrastructure, mostly municipal owned infrastructure firms such as waste treatment plants or water providers. They are also less innovative than scale and information intensive firms, which is to be expected.

The constant in the models is the mean intercept for every firm. The random effects model estimates a separate intercept for every firm. The intercept in Tables 7.3 and 7.4 is the mean log odds based on all firms odds to be innovative when all independent variables are zero. However, this is nonsensical, since firm age or workers cannot be zero. The mean intercept for technological innovations is log odds -1.477, which is roughly a 0.18 percent probability of a firm with zero age, workers, instruments, etc. There are 3502 unique firms in the models, and all intercepts are not printed in this thesis, since they add little value to understanding the innovation process.

Technological and non-technological innovation output and policy instrument models suggest that there is some relevant variation in the relationships. Instruments that support more acquisition of machinery and equipment are positively correlated with innovative outputs, whereas instruments that support innovation are with new products but not processes. Marketing and export promotion and training and skills development instruments — both more akin to soft skills development — are very likely to have innovative firms participating. The question is whether these relationships are causal in a way that turns non-innovative firms into innovative ones.

Other investigations into the instrument mix should expect non-uniform relationships between instruments and innovation outputs. Since this thesis is not mainly focused on the effects of instrument mix, interaction effects are not investigated further. These could be, for example, about firms with investments and marketing and export promotion, together. This is one possible avenue for further research based on the same dataset.

The models here also suggest that researchers should be cautious when modelling innovation outputs. There is variation, even among technological innovations, between new products and services. These should be taken into account, and research hypotheses should be more exact.

Results suggest that there are instruments that are positively related with outputs and instruments that are not. For example, firms participating in consulting instruments display no positive or negative significant relationships with any innovation output. With these instruments, no effect might be detected when investigating instruments with innovation strategies.

Innovation strategies also differ in terms of output, as seen in Chapter 6.3. The anticipated effect from policy instruments to certain types of innovation strategies is expected to be correlating with outputs. For example, firms with product innovations and more science based strategy are also expected to be more related with investment or innovation and R&D instruments.

The overall impression from the models presented in this chapter suggests that policy instruments and innovation activities can have significant positively correlating relationships. This also suggests that policy instruments can have a possible influence on the choice of innovation strategies. In the next chapter, 8, the relationship between the dynamics of innovation strategies and policy instruments is investigated. If it would turn out that there are no significant relationships between innovation outputs and policy instruments, it would be plausible to suggest that they have no effect on innovation strategies as well.

These models indicate that policy instruments are related to innovative activities, which was the aim of this chapter. Policy instruments, at least some of them, are related to innovation outputs. In further chapters, the relationship between policy instruments and strategies is tested.

Table 7.3: Technological innovations. Model results.

	Dependent variable:							
	Technological innovations	Product innovations	New products	New services	Process innovations	New process	New distribution	New support system
	Generalized linear mixed model with binary outcome and random intercepts							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Consulting	0.128	0.162	0.125	0.168	0.058	0.057	0.109	−0.098
	(0.161)	(0.155)	(0.172)	(0.204)	(0.149)	(0.157)	(0.221)	(0.166)
Financial	0.203	0.043	0.173	−0.318	0.202	0.247	0.066	0.143
	(0.240)	(0.231)	(0.252)	(0.342)	(0.217)	(0.226)	(0.320)	(0.237)
Innovation	0.598***	0.565***	0.533***	0.509***	0.062	0.006	−0.153	0.058
	(0.158)	(0.147)	(0.163)	(0.171)	(0.139)	(0.147)	(0.208)	(0.147)
Investments	0.983***	0.391***	0.501***	−0.144	0.835***	0.843***	0.157	0.365***
	(0.135)	(0.123)	(0.137)	(0.163)	(0.115)	(0.115)	(0.154)	(0.112)
Labour	−0.047	0.057	0.049	−0.080	0.045	−0.066	−0.030	0.091
	(0.102)	(0.107)	(0.125)	(0.139)	(0.100)	(0.108)	(0.147)	(0.110)
Marketing	0.632***	0.645***	0.851***	−0.013	0.348***	0.326***	0.357**	0.332***
	(0.127)	(0.112)	(0.122)	(0.144)	(0.109)	(0.111)	(0.143)	(0.109)
Training	0.478***	0.357***	0.400***	0.121	0.377***	0.286***	0.169	0.322***
	(0.082)	(0.081)	(0.091)	(0.099)	(0.076)	(0.079)	(0.107)	(0.078)
Mixed	0.914*	0.869*	1.533***	0.173	1.346***	1.733***	0.074	−0.098
	(0.480)	(0.445)	(0.479)	(0.532)	(0.431)	(0.436)	(0.654)	(0.526)

Continued.

	Dependent variable:							
	Technological innovations	Product innovations	New products	New services	Process innovations	New process	New distribution	New support system
	Generalized linear mixed model with binary outcome and random intercepts							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Other	1.446*	0.859	0.968	1.519**	0.332	0.628	0.992	0.574
	(0.854)	(0.737)	(0.793)	(0.674)	(0.632)	(0.624)	(0.702)	(0.608)
Science based	0.453***	0.699***	0.331**	0.744***	0.148	0.158	0.234	0.062
	(0.149)	(0.140)	(0.161)	(0.150)	(0.130)	(0.136)	(0.168)	(0.126)
Specialised supplier	−0.499***	−0.350***	−0.522***	−0.149	−0.352***	−0.220*	−0.629***	−0.262**
	(0.125)	(0.125)	(0.152)	(0.142)	(0.115)	(0.122)	(0.178)	(0.116)
Supplier dominated	−0.663***	−0.487***	−0.259**	−0.545***	−0.500***	−0.537***	0.002	−0.373***
	(0.097)	(0.096)	(0.113)	(0.112)	(0.089)	(0.094)	(0.119)	(0.087)
Supporting infras.	−0.570***	−1.187***	−1.245***	−0.821***	−0.129	−0.023	−0.449*	−0.161
	(0.157)	(0.177)	(0.230)	(0.202)	(0.146)	(0.156)	(0.231)	(0.149)
Exporter	0.362***	0.314***	0.705***	−0.132	0.274***	0.400***	0.226*	0.200**
	(0.080)	(0.084)	(0.105)	(0.097)	(0.078)	(0.086)	(0.121)	(0.085)
Workers — log	0.539***	0.318***	0.262***	0.218***	0.601***	0.563***	0.371***	0.426***
	(0.038)	(0.037)	(0.043)	(0.043)	(0.035)	(0.036)	(0.043)	(0.033)
Firm age	−0.040***	−0.057***	−0.031***	−0.069***	−0.036***	−0.044***	−0.036***	−0.025***
	(0.007)	(0.007)	(0.008)	(0.008)	(0.006)	(0.007)	(0.009)	(0.007)
Foreign owned	0.299***	0.286***	0.235***	0.195**	0.263***	0.133*	0.397***	0.283***

Continued.

	Dependent variable:							
	Technological innovations	Product innovations	New products	New services	Process innovations	New process	New distribution	New support system
	Generalized linear mixed model with binary outcome and random intercepts							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(0.076)	(0.075)	(0.086)	(0.089)	(0.070)	(0.074)	(0.093)	(0.070)
CIS2006	0.129	−0.172**	−0.232**	0.021	0.274***	0.451***	−0.252**	−0.169*
	(0.081)	(0.081)	(0.091)	(0.099)	(0.079)	(0.085)	(0.128)	(0.087)
CIS2008	0.257***	−0.249***	−0.427***	0.069	0.362***	0.644***	0.371***	−0.050
	(0.082)	(0.083)	(0.095)	(0.101)	(0.080)	(0.086)	(0.118)	(0.087)
CIS2010	−0.074	−0.677***	−0.982***	−0.184	−0.125	0.109	0.158	−0.374***
	(0.097)	(0.102)	(0.119)	(0.123)	(0.095)	(0.104)	(0.141)	(0.105)
CIS2012	−0.611***	−1.006***	−1.297***	−0.536***	−0.659***	−0.420***	−0.349**	−0.751***
	(0.108)	(0.115)	(0.138)	(0.142)	(0.109)	(0.121)	(0.170)	(0.122)
Constant	−1.477***	−1.155***	−2.127***	−1.561***	−2.502***	−3.038***	−3.766***	−2.713***
	(0.168)	(0.166)	(0.198)	(0.192)	(0.158)	(0.170)	(0.219)	(0.159)
Observations	9,155	9,155	9,155	9,155	9,155	9,155	9,155	9,155
Log Likelihood	−5,326.172	−4,989.220	−4,180.573	−3,530.397	−5,245.679	−4,709.826	−2,533.937	−4,144.359
Akaike Inf. Crit.	10,698.340	10,024.440	8,407.146	7,106.794	10,537.360	9,465.653	5,113.875	8,334.718
Bayesian Inf. Crit.	10,862.150	10,188.250	8,570.953	7,270.601	10,701.170	9,629.460	5,277.682	8,498.526

Source: Innovation Data (2018); *p<0.1; **p<0.05; ***p<0.01

Table 7.4: Non-technological innovations. Model results.

	Dependent variable:		
	Non-technological innovations	Organisational innovations	Marketing innovations
	GLMM with binary outcome and random intercepts		
	(1)	(2)	(3)
Consulting	−0.053	0.128	−0.084
	(0.143)	(0.150)	(0.151)
Financial	0.195	0.253	0.235
	(0.208)	(0.217)	(0.217)
Innovation	0.270**	0.140	0.342**
	(0.135)	(0.139)	(0.140)
Investments	0.155	0.017	0.160
	(0.112)	(0.115)	(0.117)
Labour	0.031	0.007	0.053
	(0.094)	(0.102)	(0.102)
Marketing	0.497***	0.045	0.710***
	(0.106)	(0.108)	(0.106)
Training	0.432***	0.485***	0.211***
	(0.073)	(0.075)	(0.078)
Mixed	0.625	0.183	1.074***
	(0.410)	(0.435)	(0.415)
Other	0.340	0.311	1.005
	(0.645)	(0.631)	(0.648)
Science based	0.120	0.215*	−0.074
	(0.125)	(0.127)	(0.130)
Specialised supplier	−0.627***	−0.325***	−1.066***
	(0.110)	(0.113)	(0.125)
Supplier dominated	−0.459***	−0.374***	−0.442***
	(0.084)	(0.086)	(0.088)
Supporting infras.	−0.673***	−0.445***	−1.118***
	(0.141)	(0.147)	(0.166)
Exporter	0.312***	0.230***	0.317***
	(0.073)	(0.077)	(0.082)
Workers — log	0.404***	0.419***	0.270***
	(0.033)	(0.034)	(0.035)

Continued.

	Dependent variable:		
	Non-technological innovations	Organisational innovations	Marketing innovations
	GLMM with binary outcome and random intercepts		
	(1)	(2)	(3)
Firm age	-0.031^{***}	-0.038^{***}	-0.013^{*}
	(0.006)	(0.006)	(0.007)
Foreign owned	0.224^{***}	0.263^{***}	0.162^{**}
	(0.067)	(0.069)	(0.072)
CIS2006	0.063	0.037	0.403^{***}
	(0.075)	(0.075)	(0.082)
CIS2008	-0.538^{***}	-0.758^{***}	0.031
	(0.077)	(0.079)	(0.085)
CIS2010	-0.693^{***}	-0.975^{***}	−0.135
	(0.090)	(0.095)	(0.100)
CIS2012	-0.983^{***}	-1.235^{***}	-0.365^{***}
	(0.100)	(0.108)	(0.113)
Constant	-1.041^{***}	-1.421^{***}	-1.887^{***}
	(0.147)	(0.151)	(0.159)
Observations	9,155	9,155	9,155
Log Likelihood	−5,573.855	−5,156.260	−4,893.234
Akaike Inf. Crit.	11,193.710	10,358.520	9,832.468
Bayesian Inf. Crit.	11,357.520	10,522.330	9,996.275

Source: Innovation Data (2018); *p<0.1; **p<0.05; ***p<0.01

8. PUBLIC SECTOR SUPPORT AND DYNAMICS OF FIRM INNOVATION STRATEGIES

The structure of this chapter is as follows. First, I explain the aim of the chapter, the research questions and objectives. Second, I describe where it fits in the theory provided in Chapters 2 and 3. Third, I explain the method to reach the objectives. Fourth, I estimate the results. Fifth, I interpret the results. Sixth, I discuss how it relates to the rest of the thesis.

8.1. Summary of relevant established results

The aim of this chapter is to estimate the possible relationship between public support and dynamics of firm innovation strategies.

Sections 6 and 7 laid the foundation for this estimation. In the former, dynamics of firm innovation strategies are estimated and described. Firms shift between patterns of innovation often, changing their innovative activities in relatively short periods. In the latter section, there is evidence that there is a positive or negative relationship between some public support instruments and innovative activities.

In this section, this relationship is under deeper scrutiny. I estimate whether firms are more likely to belong to any pattern of innovation when they receive public support. The estimation method is described in Chapter 8.2. The fit between public support and innovative activities is described in Chapters 2 and 3.

Results from Chapter 6.3 show that there are five distinct patterns of innovation: science based, open innovation, internal strategies, supplier based and market oriented. In addition, a sixth category is available when firms indicated no innovative activities during the period.

Every pattern of innovation is characterised by strategic choices while doing innovative activities. Firms rely on different inputs, sources of information, cooperation networks and appropriation methods and generate different innovative outputs. Every pattern of innovation describes a possible path in reaching innovation outputs.

Public support has been categorised into ten groups based on supported activities. These are collaboration programmes, consulting, training and skills development, marketing and export promotion, innovation and R&D support, investments support, mixed support, labour support, financial guarantees and direct subsidies.

Results from Section 7.4 show that there is significant variation between different types of innovative outputs and public support. The main goal of innovation related public support is to increase firm innovativeness and, therefore, to increase economic activities. Public support related to innovation and R&D, investments, marketing and export promotion and training and skills development is indeed positively related with technological innovations.

Some other policy instruments, such as consulting and financial guarantees, are not related with innovativeness.

Therefore, it is expected that there are some differences in the relationships between the ways of innovating, i.e. innovation strategies and policy instruments. For example, R&D instruments should be more likely to enhance firm engagement in cooperation with universities or in-house R&D efforts.

The research question is then whether firms that are beneficiaries of public support policy instruments are more likely to be in certain patterns of innovation than firms that are not.

8.2. Multinomial logit model

I estimate the probability model for any firm to belong to any pattern of innovation, conditional on public support policy instruments. It is based on the six possible categories of innovation strategies: not innovative, internal strategies, market oriented, open innovation, science based and supplier based. I estimate four multinomial logit models with increasing levels of sophistication.

Multinomial logit models are suitable to estimate from revealed preferences data, i.e. the observed choices of firms.

There are three types of possible variables which can affect the choice of firms to choose any of the alternatives. First, there are individual specific variables, such as firm characteristics. They are the same no matter which alternative is chosen. Second, there are alternative specific variables, such as costs. In the current context, these could be costs associated with reaching any pattern of innovation. Unfortunately, these are not currently observed. Third, there are alternative specific variables with alternative specific coefficients. These are cases where utility from costs differs for alternatives. For example, time and labour costs can have different utilities in different scenarios. In the current context, if we know that it takes six months to become a science based firm (time cost), it might be different from taking six months to become a supplier based firm. The level of sophistication and capabilities are not the same.

In the models presented here, only individual specific variables are observed. There are costs available as inputs to innovative activities. However, patterns of innovation are more diversified in their strategies to include single costs to any specific pattern of innovation. For example, there is not enough information to divide training costs based on how much they aid the firm's specific strategy. One possible future research avenue would be to estimate costs in reaching patterns of innovation and, from there, to estimate the probabilities of shifting based on these alternative specific costs.

The four models with increasing sophistication are the following: (i) the base model, with only the relationship between policy instruments on the dynamics of firm innovation strategies; (ii) the base model with time controls; (iii) the base model with time and firm specific controls; (iv) the base model with time and firm specific controls and state dependency.

The full model equation in general form is the following:

$$P(y_i = j) = \frac{\exp(\alpha_j + \sum_{k=1}^{K} \beta_{jk} X_{ik})}{1 + \sum_{h=2}^{J} \exp(\alpha_h + \sum_{k=1}^{K} \beta_{hk} X_{ik}))} \tag{8.1}$$

where:

j = 2, ..., J (6)
K = 22 (in the full model)
X = independent variables
α = intercepts
β = coefficients

For the reference category, the model simplifies to:

$$P(y_i = 1) = \frac{1}{1 + \sum_{h=2}^{J} \exp(\alpha_h + \sum_{k=1}^{K} \beta_{hk} X_{ik}))} \tag{8.2}$$

The first three models — the base model and with time and firm controls — all estimate firm preferences to choose certain patterns of innovation for their innovative activities, without taking account the unobserved preference of choosing any alternative. This is not logical, as firms have path dependency and some preferences for their actions. Without state dependency, this would mean that firms are free to choose any alternative without any constraints in every period.

To account for path dependency, previous behaviour is taken into account. The fourth model is conditional on the initial value on the dependent variable in the previous period.

The full model controls for time, firm specific characteristics and state dependency. Firm controls are the same as in Section 7 and shown in Table 7.2.

For calculation references, see Croissant (2017).

8.3. Estimation of the relationship between dynamics of innovation strategies and public sector support

The base model is in Appendix XI, the base model with time controls is in Appendix XII, the base model with time and firm specific controls is in Appendix XIII and the full model with all controls and state dependency is in Table 8.2.

The reference category in each model is not innovative, i.e. firms not having any innovative strategies and not belonging to any pattern of innovation. Therefore, the interpretation of model coefficients becomes comparative to not belonging to any pattern of innovation.

The interpretation of coefficients is therefore the log odds of belonging to a pattern of innovation compared to not belonging to any conditional on receiving public support, all else being constant. In the base model, the first significant positive coefficient is 0.398 for market oriented patterns of innovation. It means that firms have positive and significant log odds of 0.398 to belong to the market oriented pattern of innovation, in comparison to being not innovative. Log odds of 0.398 is about 60% probability.

The comparison with logit models presented in Chapter 7 is apparent. In the random effects logit models, the dependent variable is binary, whether firms are innovative or not. Here, the dependent variable can take six possible states, of which five are a variation of innovative and one is not innovative. Therefore, it is a special case of the model presented in Chapter 7, where innovativeness is divided into groups based on strategies.

The Akaike information criteria and Log likelihoods become smaller when models are controlled for time, firm and state dependency. The latter especially seems to describe the underlying data better. Both these statistics suggest that the model with state dependency is more appropriate to describe the process.

The coefficients of the models cannot be compared directly between models, because the variance of the error term is different. Coefficients within a model can only be compared with each other.

Lastly, this model is currently a pooled multinomial logit model, where the assumption is that standard errors of each observation are uncorrelated. However, since it uses panel data where many firms are represented multiple times, this is clearly violated. Therefore, the standard errors in these models are clustered based on firms.

In general, the results here support the results from Chapter 7, that there is significant variation between different public support policy instrument types and innovative activities. Here, the general result would be that there is significant positive and negative correlation between some policy instruments, and some policy instruments seem to have no relationship with innovative firms.

The results are interpreted by policy instrument type in detail. The results from the full model with state dependency is considered to be superior to base models.

Consulting instruments are not related with changes from the not innovative state to any pattern of innovation. Firms that are beneficiaries of consulting instruments are not more likely to be part of any pattern of innovation. The results from the model in Table 8.2 and Tables 7.3 and 7.4 in the previous chapter suggest that firms participating in instruments which are providing consultancy are not more likely to be innovative or to engage in any innovation strategies.

The base models in Appendices XII and XIII show some significant positive correlations with the market oriented pattern of innovations and others, but the results disappear when state dependency is taken into account.

Financial guarantees also have very weak relationships with innovative activities in the models presented here. There are no significant correlations in the base models. In the full model, there is positive significant correlation with market oriented strategies, suggesting that firms that are beneficiaries of instruments based on state financial guarantees are more likely to engage in market oriented innovation strategies than to be not innovative. However, there are no significant results with any other pattern of innovation.

Innovation and R&D based policy instruments show positive and significant relationships with three patterns of innovation throughout all models. The results suggest that firms participating in innovation and R&D instruments are more likely to belong to market oriented, open innovation and science based patterns of innovation than to be not innovative. However, there is no significant relationship with internal strategy and supplier based patterns of innovation.

The coefficients in all models are highest for science based models, followed by open innovation and then market oriented patterns of innovation. The likelihood to belong to the science based pattern of innovation, which is defined by the highest share of R&D within the firm, outsourced R&D and partnerships with universities, has the biggest probability. The results suggest that firms participating in innovation and R&D based policy instruments truly exhibit traits in their behaviour that are related with more science based activities.

Policy instruments based on investments are positively and significantly correlated with four patterns of innovation — market oriented, open innovation, science based and supplier based — in all models. Firms that are beneficiaries in investment based policy instruments are more likely to belong to these patterns of innovation than to be without innovative activities.

The coefficient is highest for the supplier based pattern of innovation, meaning that the probability of belonging to a supplier based pattern of innovation is largest compared to being not innovative when firms are beneficiaries of investment instruments. This is intuitively correct. Investment instruments are usually public support for firms to acquire new machinery or technology with some discount, without any specific R&D or other activities included. For example, new ventures can purchase new machinery for their manufacturing that increases their productivity without any modification to the machinery itself. This indicates that the main sources of innovation are suppliers and arise from partnerships with them.

The only pattern of innovation without any significant relationship with investment instruments is internal strategies. These are mostly firms which are subsidiaries and belong to a group. One possibility is that they have other possible sources for financing their innovative activities, so there is no relationship with investment instruments.

Labour support instruments show no relationship with patterns of innovation and a weak relationship with the open innovation pattern of innovation. The coefficient is negative, suggesting that firms participating in labour support instruments are less likely to belong to the open innovation pattern than to be without innovative activities. From estimates in Chapter 7.4, it is already clear that labour support instruments are not related with innovative outputs for firms.

In general, there seems to be a very weak relationship between labour support instruments and innovative activities, especially when combined into patterns of innovation. This suggests that firms participating in labour support instruments are not more likely to be innovative or exhibit certain defined innovative strategies. If the only significant relationship between labour support instruments and the open innovation pattern of innovation is taken at face value, it seems that firms participating in labour support instruments become less innovative in the end.

Labour support instruments are basically policies to induce firms to hire certain unprivileged labour groups or create jobs in special areas that usually have high unemployment or a lack of opportunities. Firms receive a discount for a specific period to hire such labour or create such jobs. One possibility is that firms participating in these instruments are not looking for innovation, but rather aim for the cheapest labour possible, thus reducing labour costs within the firm. However, in models here, the only significant relationship is with one type of pattern of innovation and not with others. I remain unconvinced that the result is not spurious.

Marketing and export promotion instruments show a positive and significant relationship with three patterns of innovation — market oriented, open innovation and science based. There are positive relationships with the supplier based pattern of innovation as well, but the effect disappears when state dependency is taken into account. Results from models suggest that firms participating in marketing and export promotion instruments are more likely to belong to these three patterns of innovation compared to being without innovative activities, even when their previous states are taken into account.

The coefficients are highest for the science based pattern of innovation, yet the differences are small. Marketing and export promotion instruments deal with possible market penetration assistance, such as teaching skills, developing export plans, visiting new markets, presenting at trade fairs, etc. One indication is that these three patterns of innovation are also with emphasis more on product innovations as outputs and with higher shares of marketing innovations, shown in Table 6.4. I would like to emphasise that innovation outputs were not included in the estimation of patterns of innovation, only inputs and management choices. The results here confirm that instruments which are supposed to provide for certain outputs are indeed positively correlated with the activities they are supposed to benefit and their outputs. I cannot claim that this is a direct causal relationship, but it is one indication that policy instruments at least provide some evidence that they are linked with stated goals.

Internal strategy and supplier based patterns of innovation are not more likely than being without innovative activities, if firms receive marketing and export promotion instruments. This is in line with the statement from the previous paragraph, that firms receiving this type of support are already belonging to other patterns of innovation that exhibit evidence from supported activities.

Training and skill development instruments are positively and significantly related with all patterns of innovation. The first note is that firms that are beneficiaries of such instruments are more likely to be innovative, in general, as seen in Chapter 7.4. These instruments are mainly aimed at workers to get training or retraining or to develop new skills at workshops. Firms with workers or managers participating in these programs are more likely to be innovative than without innovative activities, even when the previous state is taken into account. The highest probability corresponds with being in the open innovation or internal strategy patterns of innovation.

Results for mixed policy instruments and other policy instruments are not significant in any category. There are very few observations in these policy instrument types, which makes the results less credible as well. Some coefficients are very large and have very large standard errors, and there are not enough observations to estimate probabilities at all.

There is a small downward trend in the data, shown in Figure 5.5. Time constants are all significant and with negative coefficients, since the base category is the earliest for every model.

Firm specific controls become mostly not significant in the full model. Firm age in years has very small coefficients and is significant for only the internal strategy and supplier based patterns of innovation. It seems that firm age is not a very relevant characteristic to differentiate between possible shifts in patterns of innovation.

Exporting firms are more likely to be in the internal strategy or market oriented patterns of innovation than without innovative activities. There is no significant difference when other patterns of innovations are compared with firms without innovative activities.

Larger firms are more likely to be in the internal strategy, open innovation or science based patterns of innovation than without innovative activities. They are more likely to be market oriented and supplier based as well than without innovative activities. However, the probabilities for the latter are smaller than for the former categories. In general, larger firms are more likely to be innovative and exhibit certain behavioural traits.

Open innovation and science based firms have the most formal partnerships with other participants in the innovation system, such as clients, suppliers, competitors, universities, etc. It takes more capabilities to manage these relationships. Larger firms have the advantage of dedicating special staff to these strategic choices.

The internal strategy pattern of innovation is largely shown through subsidiary relationships. They are more likely to be larger than average firms in this dataset. The internal strategy pattern is also positively and significantly related with being foreign owned. In brief, holding all else constant, being foreign owned increases the likelihood of belonging to the internal strategy pattern of innovation when compared with being without innovative activities.

Foreign ownership is also negatively correlated with the supplier based pattern of innovation. Firms are less likely to be supplier based than without innovative activities when they are foreign owned. This means that for foreign owned firms, this pattern of innovation is even less likely than being not innovative at all. The supplier based pattern of innovation is not very likely for subsidiary relationships and is not relevant for firms with group partnerships.

All previous states are relevant for every category. The base reference for previous states is being without innovative activities. The coefficients are therefore a bit comical to interpret. For example, firms that were in the internal strategy pattern of innovation in the previous period, compared to firms that were not innovative in the previous period, are more likely with log odds of 2.63 to be in the internal strategy pattern of innovation compared to firms that are not innovative in the current period. This is about 93% probability, which is rather high.

The next column is the market oriented pattern of innovation. The interpretation is that firms in the internal strategy pattern of innovation in the previous period, compared to firms without innovative activities, are more likely with log odds of 1.718 to be in the market oriented pattern of innovation in the current period, when compared to being without innovative activities.

Positive coefficients for lagged states mean that firms that were within any pattern of innovation in the previous period are more likely to be in any pattern of innovation in the cuerrent period as well. This is innovation persistency, as firms that innovate continue to do so.

The highest persistency is mostly in the same pattern of innovation that the firm was in during the previous period. The simple transition pattern matrix was already presented in Chapter 6.3, which shows underlying transition probabilities without taking any additional information into account. For most patterns of innovation, the most probable course is the same pattern of innovation in the next period. However, the probabilities are less than 50% in all patterns of innovation, meaning that shifting between states is likely.

Table 8.1 highlights results described here.

The next chapter describes another estimation of the same concept with a different technique. Results from this chapter show that not all policy instrument types should be included in further models. Multi-state Markov models used in the next chapter use innovation and R&D instruments, training and skill development instruments, investment instruments, and marketing and export promotion instrments as covariants, since they showed the most significant relationships with firm innovation strategies.

Table 8.1: Relationship between public support and dynamics of patterns of innovation

Policy instrument	Relationship with patterns of innovation
Consulting	no significant relationship
Financial guarantees	no significant relationship
Innovation and R&D	positive relationship with shifting to market oriented, open innovation and science based pattern of innovation; highest for science based
Investments	positive relationship with shifting to all patterns of innovation, except internal strategy; highest for supplier based
Labour support	no significant relationship; weak negative relationship with open innovation
Marketing and export promotion	positive relationship with shifting to market oriented, open innovation and science based pattern of innovation; highest for science based
Training and skill development	positive with shifting to all patterns of innovation; highest for open innovation
Mixed support	no significant results
Other	no significant results

Table 8.2: Public support and patterns of innovation. Full model with time and firm specific controls and state dependency estimates.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
Consulting	−0.434	0.334	−0.097	−0.102	0.043
	(0.278)	(0.204)	(0.287)	(0.354)	(0.218)
Financial	−0.214	0.574**	0.460	−0.216	0.341
	(0.490)	(0.288)	(0.417)	(0.630)	(0.308)
Innovation and R&D	−0.073	0.647***	0.803***	1.599***	−0.008
	(0.298)	(0.192)	(0.246)	(0.264)	(0.220)
Investments	0.413*	0.696***	0.532**	0.907***	1.143***
	(0.236)	(0.168)	(0.228)	(0.259)	(0.149)
Labour	−0.298	0.028	−0.432**	−0.190	−0.096
	(0.184)	(0.136)	(0.206)	(0.264)	(0.135)
Marketing	0.279	0.616***	0.563***	0.879***	0.196
	(0.206)	(0.151)	(0.201)	(0.239)	(0.162)
Training	0.593***	0.276**	0.761***	0.514***	0.343***
	(0.138)	(0.110)	(0.149)	(0.198)	(0.105)
Mixed	−5.295	−1.319	−5.202	−3.868	−0.488
	(9.892)	(0.886)	(9.846)	(9.596)	(0.869)
Other	−2.665	0.490	2.328	1.554	1.739
	(9.892)	(1.699)	(1.561)	(1.655)	(1.395)
CIS2006	−1.236***	−0.587***	−1.118***	−1.204***	−0.163**
	(0.130)	(0.093)	(0.136)	(0.182)	(0.081)
CIS2008	−0.774***	−0.253***	−0.872***	−1.187***	−0.407***
	(0.119)	(0.090)	(0.135)	(0.190)	(0.085)
CIS2010	−1.090***	−0.843***	−1.291***	−1.784***	−0.748***
	(0.121)	(0.093)	(0.137)	(0.195)	(0.088)
CIS2012	−1.163***	−1.407***	−1.756***	−2.093***	−1.304***
	(0.135)	(0.114)	(0.169)	(0.239)	(0.108)
firm_age	−0.056***	−0.0002	−0.009	−0.007	0.023**
	(0.012)	(0.010)	(0.014)	(0.019)	(0.009)
firm_exporter	0.383**	0.417***	0.244	0.421	0.051
	(0.174)	(0.118)	(0.185)	(0.272)	(0.100)

Continued.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
firm_log_worker	0.622***	0.300***	0.618***	0.641***	0.287***
	(0.061)	(0.050)	(0.065)	(0.082)	(0.047)
firm_foreign_owned	0.928***	−0.188*	0.260*	−0.001	−0.200**
	(0.124)	(0.104)	(0.140)	(0.191)	(0.100)
lag_strategy_Internal	2.630***	1.718***	1.969***	1.957***	1.202***
	(0.183)	(0.183)	(0.262)	(0.459)	(0.181)
lag_strategy_Market	1.586***	2.409***	2.087***	2.629***	1.410***
	(0.176)	(0.119)	(0.205)	(0.331)	(0.116)
lag_strategy_Open	2.741***	2.731***	4.152***	3.886***	1.819***
	(0.236)	(0.200)	(0.235)	(0.374)	(0.208)
lag_strategy_Science	1.489***	3.066***	3.236***	5.742***	1.540***
	(0.509)	(0.315)	(0.386)	(0.411)	(0.373)
lag_strategy_Suppliers	1.184***	1.397***	1.319***	1.797***	1.630***
	(0.183)	(0.129)	(0.226)	(0.364)	(0.103)
Constant	−4.263***	−3.090***	−5.036***	−6.268***	−2.622***
	(0.238)	(0.178)	(0.271)	(0.400)	(0.166)
Observations	5344				
Akaike Inf. Crit.	12,940.120				
Log likelihood	-6,359.991				

Note: *p<0.1; **p<0.05; ***p<0.01

9. UNDERSTANDING DYNAMICS OF FIRMS INNOVATION STRATEGIES

In this chapter, the emphasis is on the dynamics side of firm innovation strategies. To understand how often firms shift between their strategies, results from previous estimations are taken into account and a new model is estimated. Markov chain models are estimated to investigate the intensity with which firms transition from one strategy to another and how much these intensities are influenced by policy instruments.

Compared to some more traditional regression model methods (see Imbens and Wooldridge (2009) and Zúñiga-Vicente et al. (2014) for some examples), Markov models have the advantage of estimating a complex set of possible trajectories over time. With more traditional regression methods, this becomes problematic for estimation. When previous results are taken into account, firms in the dataset used here can have six different innovation strategies (including the not innovative state) over a ten year period in two year increments. This results in a total of 7776 different combinations of trajectories for a firm.

Naturally, a set of different trajectories as large as this is not feasible for humans to comprehend. To understand the dynamics of innovation strategies, all possible trajectories are taken into account, but results are based on shifts between different trajectories. The probabilities of choosing another trajectory next and which one it would be is the object of interest.

This type of modelling is more popular in health-related fields, but there are examples from economics as well, e.g using Markov transition models to investigate labour force transitions (Joutard et al., 2012), financial time series (Nystrup et al., 2015) or, more aligned with this thesis, R&D persistency (Rammer and Schubert, 2018).

A related stream of literature has used Markov models or transition probability matrices to investigate the persistency of innovations (Antonelli et al., 2013; Cefis, 2003; Cefis and Orsenigo, 2001; Roper and Hewitt-Dundas, 2008). In this case, Markov models are used to investigate whether firms are more likely to be innovative in the next period or what type of innovations are more likely. The emphasis is on the output side of innovations and whether they have innovations or not.

The investigation here differs somewhat from the above example. I investigate *how* firms are innovating currently and in the next period. This is closely related to the work of Hollenstein (2018), based on the Swiss example.

Results from Chapter 6 already show a simple transition probability matrix. From this, it is reasonable to expect that firms have a tendency to shift between different strategies. Markov models allow covariates. Therefore, estimations in this chapter are mostly concerned with how much these transition probabilities are increased or decreased when firms receive public support from policy instruments.

I will describe the method first in Section 9.1 in detail, since multi-state Markov models are not very common in policy support analysis. In Section 9.2, I will estimate several sets of models to describe the dynamics of firm innovation strategies in detail.

9.1. Multi-state Markov models with continuous time

Multi-state models or Markov transition models have often been used with panel data to describe and analyse the movement of individuals or firms between different stages. In the models, these stages are usually referred to as states.

Markov transition models estimate transition probabilities if they are modelled in discrete time and transition intensities if they are modelled in continuous time. A discrete time Markov-chain is a system where transitions between states happen only on discrete time intervals. In the example of firm innovation strategies, it would mean that all firms shift between their chosen strategies at specific time intervals simultaneously, usually at the time of measurement. This assumption is unlikely to be realistic. Discrete state Markov chains are often used for their easier interpretability, even though the underlying data is most likely continuous.

I estimate transition intensities (defined later) in a continuous time Markov chain setting. Even though it is more complex, this type of modelling is more in line with the underlying process of shifting between strategies.

Markov chain models are used to describe how observed units move between a set of discrete states whereby the number of states in the analysis is fixed. States used in this analysis are based on patterns of innovation estimated in Chapter 6. Figure 9.1 describes the possible transitions in a three-state Markov model. The arrows represent possible changes between states. Notice that this example model allows transitions between all states. This type of model can estimate transition intensities between states, i.e. the instantaneous risk of moving from one state to another. The general formula for estimating transition intensities is in Equation (9.1). Markov models are covered in depth in Cox and Miller (2001).

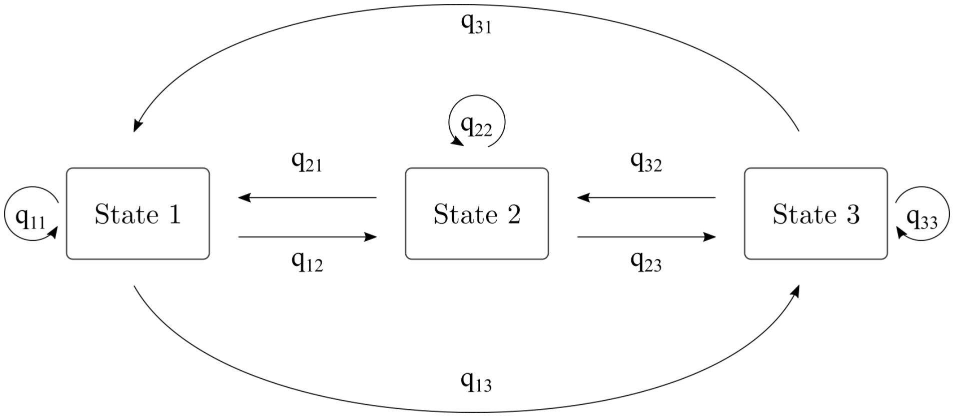

Figure 9.1: Multi-state model for innovation strategies.

Suppose a firm is in state $S(t)$ at time t. The movement between states $1, ..., R$ is governed by transition intensities $q_{rs}(t, z(t))$, whereby $r, s = 1, ..., R$. These depend on time t and on a set of explanatory variables $z(t)$. In the end, the q_{rs} or intensity represents the instantaneous risk of moving from state r to state $s \neq r$

$$q_{rs}\left(t, z\left(t\right)\right) = \lim_{\delta t \to 0} P\left(S\left(t + \delta t\right) = s \mid S\left(t\right) = r\right) / \delta t \tag{9.1}$$

The continuous Markov model assumes that the underlying Markov process is not happening strictly at the times of our measurement but can also evolve between those times. In the case of this thesis, it means that this model adds flexibility, so that firms can change their strategies at some random time t that is *between* surveys.

If we take the example from Figure 9.1, then there are $r = 3; s = 3$ possible movements between states, so q_{rs} forms a $r \times s$ matrix Q with rows that sum to zero, so that the diagonal entries are by definition $q_{rr} = -\sum_{s \neq r} q_{rs}$. An example of matrix Q in a three-state case where all movements are allowed is in Equation (9.2).

$$Q = \begin{pmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ q_{31} & q_{32} & q_{33} \end{pmatrix} \tag{9.2}$$

The off-diagonal elements in matrix Q (in eq. (9.2)) represent the transition intensities of moving from one state to another. The diagonal elements represent the intensity of persistence, such that the firm will remain in its current state. This is not very intuitive with transition intensities, since they show the *instantaneous* risk. Also, since continuous time Markov models show transition intensities at δt, which is asymptotically negligible, these should be converted to transition probabilities for easier interpretation. However, with continuous time Markov models, the time δt can be chosen arbitrarily. I will present some probability matrices as well having δt with different year values, which will represent the probability that firms shift between different states at some point during this time.

The likelihood to estimate the transition intensities are calculated from the transition probability matrix $P(t)$. It is possible to show that the transition probabilities can be calculated from the exponent of the transition intensity matrix (eq. (9.3)). Where the $\exp(Q)$ is the matrix exponential, not the exponent of individual elements. Difficulties in calculating this matrix exponent are discussed in Moler and Loan (2003).

$$P(t) = \exp(tQ) \tag{9.3}$$

The panel data setting for continuous time Markov models deals with observations that are gathered at fixed time intervals in this case. The observations are gathered at irregular time intervals for specific subjects, and some firms did not respond to the survey in every wave. The full likelihood function is then the product of probabilities of transition between observed states, over all individuals i and observation times j:

$$L(Q) = \prod L_{i,j} = \prod_{i,j} P_{S(t_{ij})S(t_{i,j+1})} \left(t_{i,j+1} - t_{ij}\right) \tag{9.4}$$

Each component $L_{i,j}$ is the entry of the transition matrix $P(t)$ at the $S(t_{ij})$th row and $S(t_{i,j+1})$th column, evaluated at $t = t_{i,j+1} - t_{ij}$. The full likelihood $L(Q)$ is the product of all terms $L_{i,j}$ over all individuals and all transitions.

For models with all six states, a simplification has to be made for likelihood calculations. An assumption is made that firms have remained in the same state for the whole duration between two measurements. In the case of this thesis, it would mean that firms would be in the same pattern of innovation for the whole duration between two survey waves and would only shift once between measurements. This simplification take the form of:

$$L_{i,j} = \exp\Big(q_{S(t_j)S(t_j)} \left(t_{j+1} - t_j\right)\Big)\, q_{S(t_j)S(t_{j+1})} \tag{9.5}$$

since the state $S(t_j)$ is assumed to be the same for the whole interval between t_j and t_{j+1} with a known transition to state $S(t_{j+1})$. This would be the contribution to the full likelihood $L(Q)$. This type of model is called continuous time Markov model with *exact* times in this thesis. Simplification is needed to reduce the complexity of calculations when all six states in patterns of innovation are included in the model.

However, it is not true that the likelihood function shown in Equation (9.4) with more flexibility estimates the model without any bias. This type of function assumes that the data is collected *intermittently* but as snapshots describing the state of the observation at a fixed point in time. However, the data used in this thesis is collected in a way that describes the state for the whole period, before the observation time. As described in Chapter 4.1, innovation survey questions are about activities that may have happened at any time during the observed period that is covered in the survey. This means that the data used in this thesis is not exactly describing the current state at a fixed time point, but rather the whole period before this time point. However, the function for the *exactly* observed model with the likelihood function shown in Equation (9.5) assumes that the observation was in the described state for the whole period between two observations, which also may not be true. The firm might have created their innovative activities in the last year of the observed period and shifted their innovation strategy at some point between two observation periods. In the exactly observed model, this flexibility is lost.

Therefore, it is likely that the intermittently observed model overestimates the transition intensities in the model, and the exactly observed model underestimates the transition intensities. For these reasons, both of these model types are presented for the three-state model. Due to calculation complexity, only the exactly observed models can be estimated and presented for the six-state model.

The calculations of the above described likelihoods are performed with the *msm* package in *R*, see Jackson (2011) for further details.

Covariates are introduced to the model to estimate its relation with transition rates q_{rs}. The transition intensity can be modelled as a function of these variables (Marshall and Jones, 1995). In the model described in Equation (9.1), the transition intensity matrix elements are replaced by:

$$q_{rs}\left(z_i\left(t\right)\right) = q_{rs}^{(0)} \exp\left(\beta_{rs}^{T} z_i\left(t\right)\right) \tag{9.6}$$

whereby $z_i(t)$ is the covariate vector for every ith individual at time t. $q_{rs}^{(o)}$ is the baseline for the transition $r - s$, and β_{rs}^{T} is the estimator associated with the variable $z_i(t)$ for the transition $r - s$. $q_{rs}^{(o)}$ is the expected value of the intensity function when the covariate vector is zero. $\exp(\beta)$ is a rate ratio or hazard ratio, which represents the percentage increase or decline of the baseline intensity. If the hazard ratio is less than 1, the covariate has a negative effect on the baseline transition intensity. If it is more than 1, then the covariate has a positive effect on the baseline intensity. If the hazard ratio is 1, then there is no effect. For example, a hazard ratio of 1.5 means that the transition intensity is 1.5 times larger for the group where the covariant applies.

In this thesis, baseline transition intensities, hazard ratios for covariates and transition probability matrices in fixed time intervals are reported for different models.

9.2. Multi-state dynamics of firm innovation strategies and public sector support

All states analysed in this chapter are based on patterns of innovations estimated in Chapter 6. All covariates used in this chapter are based on the same policy instrument data used in Chapters 7 and 8. Transitions between different states are analysed in three- and six-state settings.

In the three-state analysis, three states can take values of not innovative, simple innovation strategies and complex innovation strategies. These are a combination of patterns of innovation that have the most similar attitudes. For example, simple innovation strategies are a combination of internal strategies, supplier based strategies and market oriented strategies, all of which rely less on cooperation, have less partnerships and knowledge sources outside of the firm than the remaining two patterns of innovation. Complex innovation strategies are, therefore, open innovation strategies and science based strategies. These rely more heavily on cooperation, outside knowledge sources and more diverse set of inputs. Simple descriptive statistics in Chapter 6.3 showed that these strategies are also harder to be attained and have more persistence, indicating it is more costly to build these capabilities.

Table 9.1 describes all states used in the analysis and how three-state and six-state analyses correspond with each other.

Six-state analysis is done with the full range of patterns of innovation available, where each state is described as one pattern of innovation.

Covariates included in the analysis correspond to four different types of innovation policy instruments. Based on estimations in Chapters 7 and 8, innovation and R&D instruments, investment instruments, training and skill development instruments, and marketing and export promotion instruments are of the most interest. These instruments showed significant positive correlations with both innovation outputs and choices to shift to certain strategies. Markov models estimated in this chapter are a step further to understanding how these instruments are related with possible shifts between different strategies.

Table 9.1: State-space for Markov models, three-state and six-state comparison of patterns of innovation.

Three-state analysis		Six-state analysis	
State 1	Not innovative	Not innovative	State 1
State 2	Simple innovation strategies	Internal strategy	State 2
		Supplier based	State 3
		Market oriented	State 4
State 3	Complex innovation strategies	Open innovation	State 5
		Science based	State 6

For both three-state and six-state analysis, all transition paths are possible for the firm. They are already present in the data, and there is no theoretical justification to limit some transitions. These possible transition paths with their respective q_{rs} elements are pictured in the figures in Appendix XIV.

With the full dataset, only those firms can be used to model Markov chains that have at least two observations. In the dataset used in this thesis, it amounts to 7962 observations. In addition, I will show results from similar models with the smaller balanced dataset, where every firm has observations for every available period — that is 654 firms with 3270 observations. As it was in Chapter 6. The small balanced panel has more observations per firm, which should yield similar results as the full model if it is representative. However, confidence intervals are expected to be larger due to a smaller total number of observations.

A minimum of two observations per firm is needed for modelling multi-state Markov models because they rely on the assumption of first order Markov chains. First order Markov chains assume that all information needed to predict future states are present in the current state. In other words, the current state holds all information about past behaviour, and no extra information is needed about previous states. In the context of this thesis, it would mean that the current state holds all firm experiences, capabilities and possibilities for searching for innovation, and we do not need any additional information about past states to look at possible future states. If all transition paths are available to the firm as described in the figures in Appendix XIV, it also means that firms in the current state are free to choose any possible future strategy in the future without any constraints. I would like to point out that being free to choose and being able to succeed in choices are not synonymous in this case. Firms might not have enough capabilities to choose any strategy they wish, or some strategies may be too costly.

Table 9.2 is a frequency table of state transitions in the three-state Markov model. There are very few pairwise observations going from ‘not innovative’ to ‘complex strategies’ and vice versa. These shifts are difficult to model, since they represent a very low share of all shifts which lead to very large confidence intervals. They also indicate that firms are not able to create complex innovation strategies very easily, most likely due to the costs and capabilities involved. Most shifts happen between ‘not innovative’ and ‘simple strategies’ and between simple and complex strategies.

Table 9.2: Frequency table of state transitions in three-state Markov model. n = 7962 obs.

From:	To: Not innovative (1)	Simple innov. strategies (2)	Complex innov. strategies (3)
Not innovative (1)	1778	575	66
Simple innov. strategies (2)	778	1563	243
Complex innov. strategies (3)	73	294	273

Table 9.3 describes the use of policy instruments by the full sample used in the Markov models. These policy instruments have been chosen to investigate their relationship with shifting between different innovation strategies as the most probable covariants based on estimations done in Chapters 7 and 8.

Table 9.3: Use of instruments in the three- and six-state Markov models. n = 7962 obs.

	2004	2006	2008	2010	2012
Observations	1449	1745	1784	1581	1403
Innovation & R&D	10	32	23	122	186
Investments	55	110	102	187	129
Marketing & export promotion	43	104	73	263	218
Training & skills development	113	336	278	545	500

The same descriptive statistics are availabe for the balanced dataset in the three-state Markov model in Appendix XV.

In the Markov model with continuous time, the estimates are transition intensities which represent the instantaneous risk of transitioning from one state to another. In Figure 9.2, there is a graphical representation of transition intensities between different states for the three-state models. There are four different versions. An intermittently observed model which allows for most flexibility and an exactly observed model, which assumes that firms were in their observed state for the whole duration between two observations. Both models are presented for the full dataset and the smaller balanced dataset. Plots for the balanced data models are in Appendix XVI. The underlying data of the transition intensity matrices are available in Appendix XVII.

It is evident that more flexible models which assume that firms might have transitioned into some other states, also between two observations, have larger confidence intervals and larger transition intensities. In essence, these models predict that firms are more likely to transition, and we should expect more shifts between strategies in time. These are so-called intermittently observed models.

Exact models show smaller transition intensities and also narrower confidence intervals. As mentioned earlier, the constraint is that firms are assumed to be in the observed strategy for the whole duration between two measurements. For the balanced dataset, it is easier to acknowledge that firms might have had the same innovation strategy for the two years between two measurements. However, for the full dataset, this assumption means that the firm might have been up to eight years in the same innovation strategy if we only observed them in the first and last period. This is not a very prevalent case in the data (see Appendix II), yielding only five firms with such a pattern. The gaps in other pattern combinations can still be from two to six years long.

The balanced dataset models show very similar transition intensities with only minor increase in confidence intervals. The full dataset with gaps is sufficient for the analysis here. Therefore, I will describe transition intensities only from the full dataset model with intermittently observed transitions as the base model. Diagonals in the transition matrices in Appendix XVII describe the intensities of staying in the same state as before. These are the negative values in Figure 9.2.

Transition intensities for not innovative firms are the smallest, meaning they have the highest probability of not shifting to any other state. The simple strategies intensities are 1.8 times larger than not innovative firms $(-0,340/-184)$. These firms are 1.8 times more likely to shift from their current strategy.

The transition intensities are highest for complex strategies, meaning these firms are most likely to transition from their current state. This is an indication of persistence. It is clear that the highest persistence is for not innovative firms to stay not innovative. Markov models show that firms with complex innovation strategies are 1.3 times more likely to shift from their current strategy than simple innovation strategy firms. This indicates that simple strategies have higher persistence than complex innovation strategies.

Building collaborative capabilities and R&D strategies is costly and difficult for firms (Ganter and Hecker, 2013; Swink, 2006). As already described in Chapter 2, it takes a lot of effort for some sectors to shift from their current technological trajectory and, consequently, change their innovation strategies.

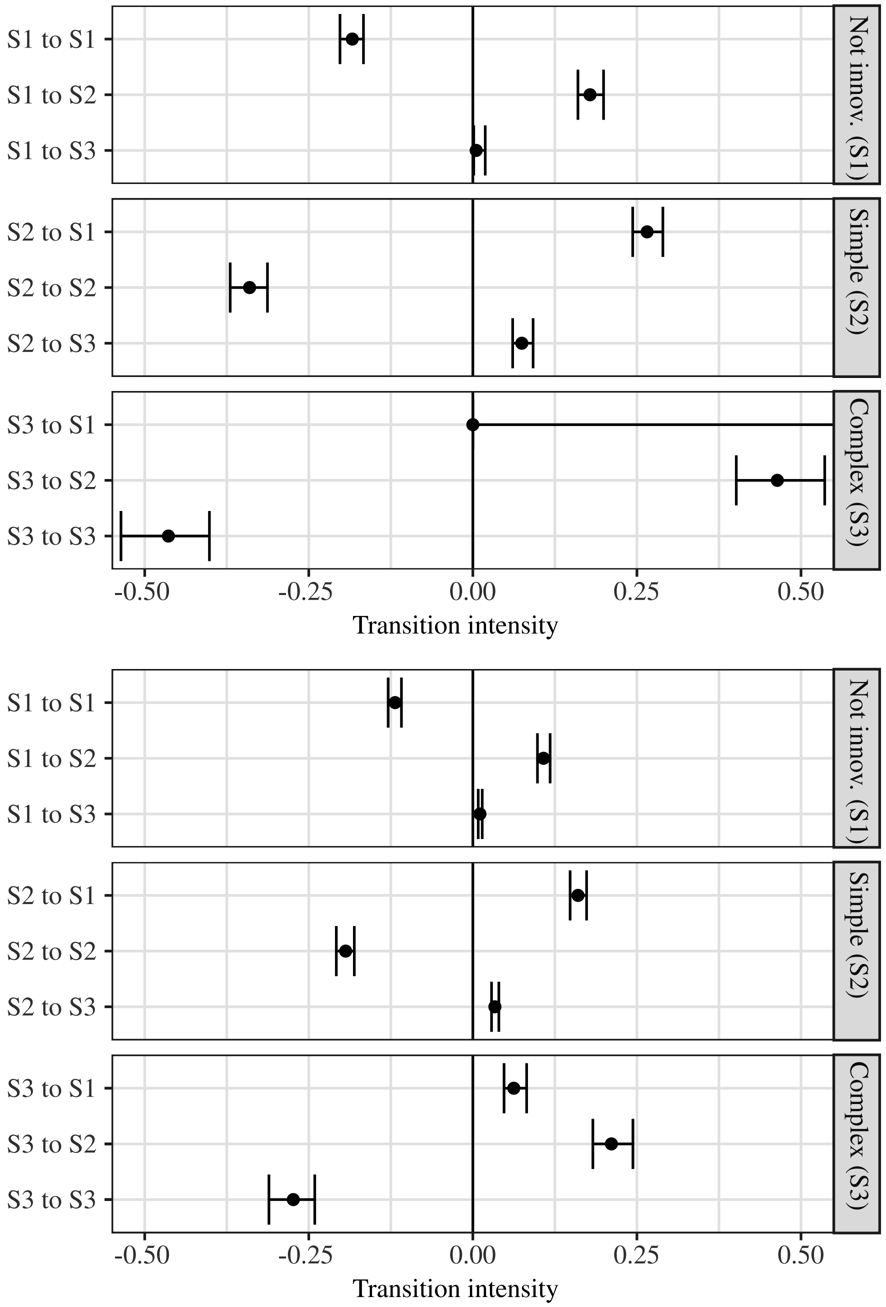

Figure 9.2: Three-state Markov model transition intensities. Upper: Full data, intermittently observed model; lower: Full data, exactly observed model.

All four models show similar results, and the intensities have different magnitudes. Models with exact transition times show smaller intensities, but relations between diagonals are almost the same.

Turning to off-diagonals, firms in the not innovative state are about 35 times more likely to transition to the simple innovation strategy state than the complex one. It seems that the probability to transition to the complex strategy state is less than one percent for not innovative firms. There are very few cases for firms to transition between these states, and this jump seems unattainable.

Firms in the simple state are about 3.5 times more likely to become not innovative than transition to the complex state. Since this state has less persistency than the not innovative state, firms then spend less time in this state and are more likely to become not innovative again.

Firms in the complex state have almost zero probability to transition to the not innovative state. This transition is too rare, and the intermittently observed model cannot estimate the intensity properly. The exact model indicates that the transition intensity is about 0.062.[1] As there are so few observations, the confidence intervals are large. Still, all models indicate that this transition has a very low intensity compared to any other, indicating that this shift is not very probable. Firms shift very often from the complex to the simple innovation strategy state. It is also possible to interpret this transition intensity as one that it is so rare that, in practice, we do not observe firms transitioning from complex strategies straight into not having any innovation strategy at all.

Another way to investigate the persistency of states is to look at mean sojourn times. This can be calculated with $-1/q_{rr}$. Sojourn time is the mean expected time that is spent in one state. In the full model with intermittently observed transitions, the mean sojourn times are 5.4 years for the not innovative group, 2.9 for the simple innovation strategies and 2.1 for the complex strategies. The discrepancy between not innovative state and other states is rather large, indicating that there is persistency of innovativeness. It has been previously shown that there is more persistency in product innovations than process innovations (Antonelli et al., 2012; Tavassoli and Karlsson, 2015).

Complex innovation strategies here should yield more product and process innovations than simple innovation strategies. The latter is mostly only process innovations. Frenz and Prevezer (2012) point out that persistency is more linked with firm-level heterogeneity instead of sector-level. Results here show that firm-level may also arise from their innovation strategy which leads to possible differences

[1] The model with intermittently observed states converges on its likelihood better without any covariants. The change in transition intensities is less than 10 percent for all other intensities. Then the transition intensity is 0.003 with 95 percent confidence intervals 0.000; 0.158.

in persistency of outputs. Persistency itself is also aligned with resource-based theories introduced in Chapter 2, where systematic capability building leads to long-term positive effects.

Figure 9.3 shows the hazard ratios for covariates used in the Markov models for the full data model. The balanced data model plots are in Appendix XVIII. The results for both models are also in tables in Appendix XIX. A hazard ratio of 1.5 means that the transition intensity is 1.5 times larger for firms that participate in policy instruments. Similarly, a hazard ratio of 0.5 means that the transition intensity is halved for firms participating in policy instruments. If hazard ratio confidence intervals cross the value level 1, then results are insignificant.

All models in Figure 9.3 and Appendix XVIII show fairly similar results. There are not many transitions where policy instruments are significant. In general, I will describe examples based on the full data model with intermittently observed transitions. I will mainly describe significant results, i.e. hazard ratios which do not cross the value 1 with their confidence intervals.

From not innovative to simple innovation strategies, investments are the only positive covariate. The hazard ratios are around 1.59, meaning they increase the probability to transfer from not innovative state to the simple innovation strategies about 1.59 times. Other instruments showed no significant relationships in increasing or decreasing the probability of transition. Chapters 3 and 5 describe how in the Estonian case there was emphasis on building new capabilities by subsidising the acquisition of physical capital. The results here seem to confirm that there is indeed some increased transitioning to supplier based strategies with investment instruments.

From not innovative to complex strategies, marketing instruments show a positive relationship with transitioning. The hazard ratios are rather large, with very large confidence intervals ranging from 2.8 to 8.9 in full dataset models. There are very few cases observed for these transitions, so these results should be seen as preliminary. More observations are needed to pinpoint the relationship between marketing and export development instruments and dynamics from not innovative and complex innovation strategies.

From simple strategies to not innovative, training and skill development instruments and investment instruments show negative relationships with transitioning. This means that these instruments reduce the probability of transitioning. Investment instruments have hazard ratios of around 0.58, so firms are 58 percent less likely to become not innovative if they have simple innovation strategies when they receive investment instruments. Training and skill development instruments have hazard ratios of around 0.77, a slightly smaller decrease in transition probability than investments. These results suggest that these instrument types may

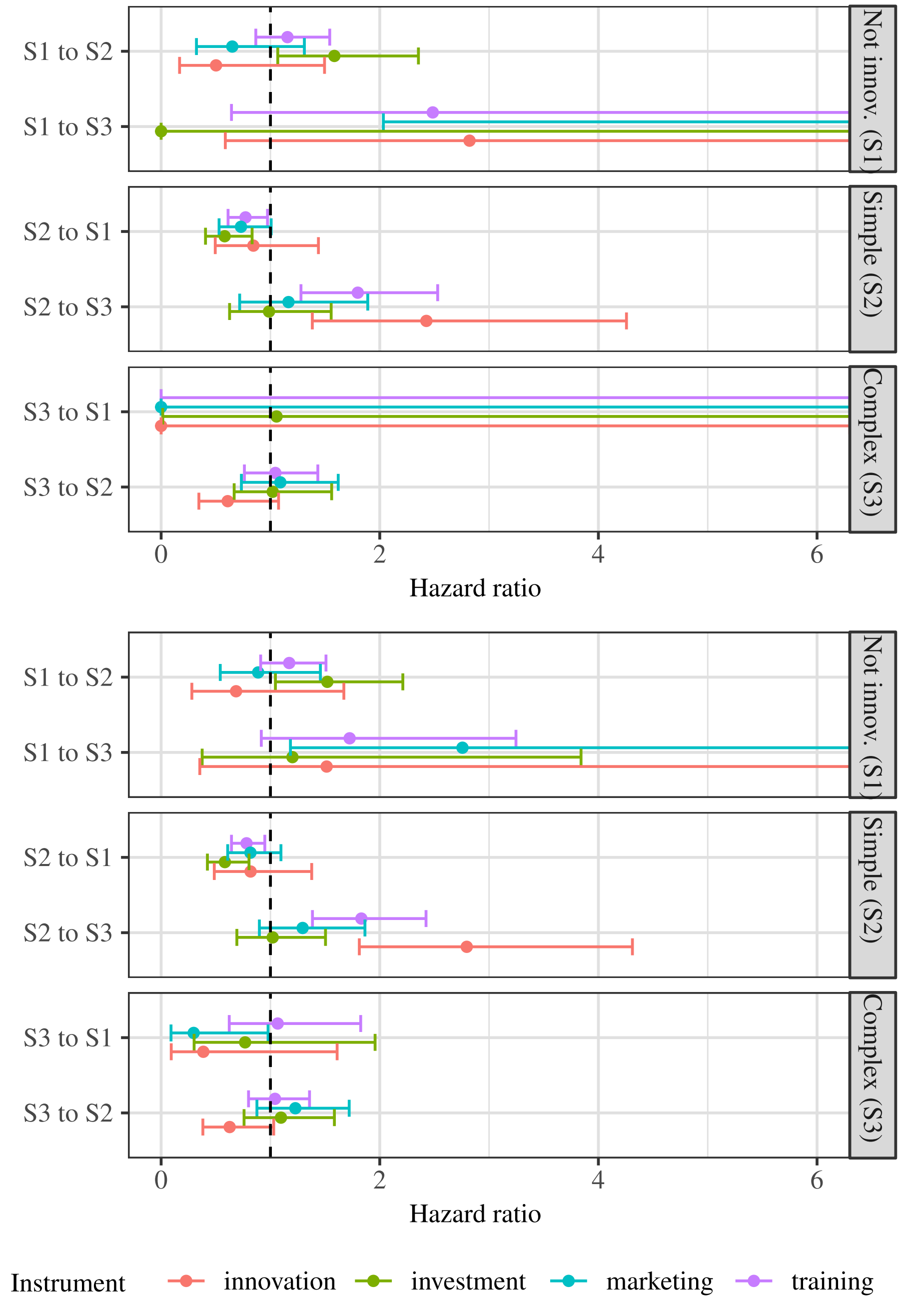

Figure 9.3: Hazard ratios for innovation policy instruments in the three-state Markov models. Upper: intermittently observed model; lower: exactly observed model.

keep firms from not becoming not innovative if they have simple innovation strategies.

From simple to complex innovation strategies, training and skill development instruments and innovation and R&D instruments increase the probability of transitioning. Training and skill development instruments have hazard ratios of around 1.8, and innovation and R&D instruments have hazard ratios of around 2.4 (2.8 in the exact model). Firms that receive innovation and R&D instruments are more than 2.4 times as likely to transition from simple to complex innovation strategies. This is the largest covariate effect in all models presented here.

From complex to not innovative or simple innovation strategies, there are no significant effects from covariates. Only marketing instruments show a reducing effect from complex to not innovative transition, but these cases are very rarely observed in the data, and the models presented here are not the best ones for interpreting this relationship.

There are many transitions where some policy instruments do not have any significant effect. It is therefore plausible that there is heterogeneity in how policy instruments incentivise firms to take up new innovation strategies or change their current one. The transition from simple to complex innovation strategies is unlikely to take place with all policy instruments in isolation.

Next, I will present the six-state Markov model. In this model, all states that are estimated in Chapter 6 are included. Since there are six patterns of innovation possible, the transition matrix is much more complex. An illustration is in Appendix XIV. However, this complexity takes into account all $6^5 = 7776$ possible transition trajectories for five observed periods, which is usually not available with typical regression models.

Table 9.4 is a frequency table of state transitions in the six-state model. As is apparent, some transitions are very rare. For example, between science based and internal strategies, there are only 15 transitions between both ways. Because some of these transitions are so rare, it is only possible to estimate Markov models where it is assumed that transitions are observed exactly and firms do not shift into other strategies between two observations. These are the same type as the exactly observed models presented for the three-state Markov models before. As was clear from previous results, exactly observed models estimate smaller transition intensities with smaller confidence intervals. It is likely that these models underestimate true transition intensities.

The frequency table for the use of innovation policy instruments is provided similarly as for the three-state models and is presented in Table 9.3. Same descriptive statistics are available for the balanced dataset model in Appendix XX and XV.

Table 9.4: Frequency table of state transitions in a six-state Markov model. n = 7962 obs.

From	To: Not innov.	Internal	Supplier	Market	Open	Science
Not innovative	1778	86	303	186	50	16
Internal strategy	119	151	64	74	35	9
Supplier based	364	69	347	175	47	22
Market oriented	305	85	217	381	85	45
Open innovation	54	58	64	99	134	31
Science based	19	6	18	49	23	85

Base estimates for transition intensities are in Figure 9.4 for the full dataset model and in Appendix XXI for the balanced dataset model. Transition intensity matrices for both models are in Appendix XXII.

The results in the full dataset and the balanced dataset are fairly similar. Therefore, I will describe the results from the full dataset as the model of interest here. The balanced dataset has larger confidence intervals due to a lower observation count. Estimates themselves are similar.

First, the diagonals in the intensity matrix estimate the probabilities of transitioning from the current state. The not innovative state has the lowest absolute value, which means that has the lowest probability of transitioning from the current state. These results are similar as in the three-state models, and the persistency of being not innovative is highest.

However, when innovation strategies are compared, the lowest value is found for science based innovation strategies which have the highest persistency. Open innovation and other innovation strategies share very similar values, especially when confidence intervals are taken into account. In the three-state model, the open innovation and science based strategies were combined, but there seems to be some discrepancy between them, although their confidence intervals overlap a bit. Firms are more apt to transition out of an open innovation strategy than from a science based strategy. It may be that open innovation strategies need less long-term commitments than science based strategies.

Off-diagonals in the transition matrices are on the right side of Figure 9.4. The six-state model shows that there are probably complementary strategies in the model. These are logically successive states. For example, firms are more likely to transition from a not innovative state to a supplier based strategy than to establish an internal strategy. From supplier based strategies, firms are most likely to go back to either a not innovative state or market oriented strategies. During these transitions, the likelihood to transition to open innovation strategies or sci-

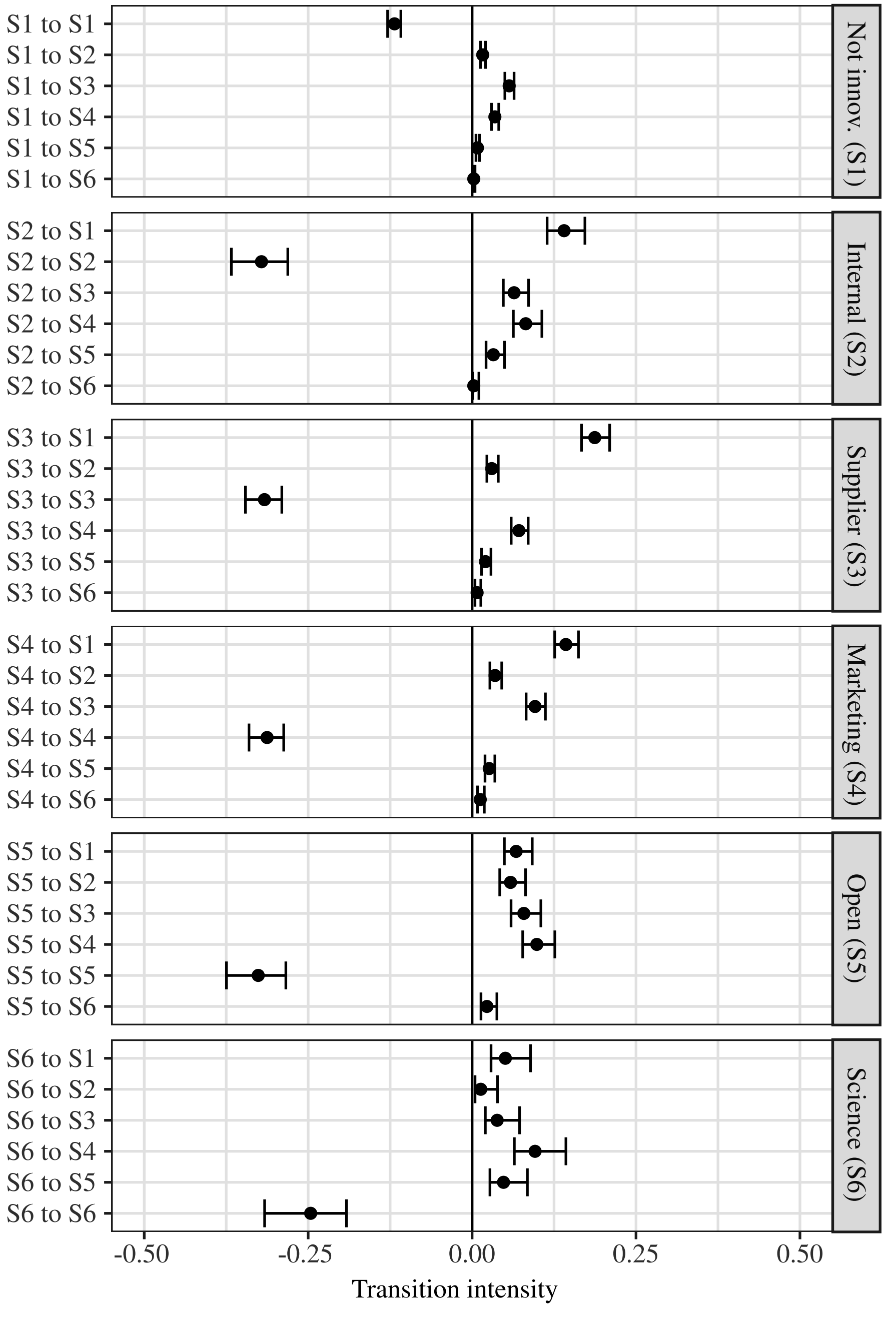

Figure 9.4: Six-state Markov model transition intensities. Full dataset model with exact transitions.

ence based strategies also increases. For example, the probability to transition to science based strategies is twice as large for open innovation firms than they are for market oriented firms.

Internal strategies seem to be a special case. Firms from other simple innovation strategies are not likely to transition to this type of strategy any more than they are likely to take up complex innovation strategies. As shown in Chapter 6, firms that chose this strategy are almost always foreign-owned and with subsidiary relationships. It seems that this type of innovation strategy which relies heavily on internal relationships can be estimated from data about innovative activities and it is separate from other innovation strategies.

Open innovation and science based firms also show the highest persistency of staying innovative. They are the only innovation strategies where the highest likelihood to transition is not into a not innovative state. These firms are most likely to transition into market oriented strategies first.

It also seems that open innovation strategies and science based strategies are not successive, but rather distinct. Firms are not very likely to transition between these two strategies, but rather into some other strategies. It seems that capabilities, choices and costs involved do not make these strategies interchangeable. Therefore, there are probably different learning-curves for both of these strategies.

Figure 9.5 shows hazard ratios for the full dataset six-state model with exact transitions. The balanced dataset model is in Appendix XXIII. Underlying data for these graphs are in Appendix XXIV.

Since there are 120 hazard ratios in Figure 9.5 and most of them are not significant, there is a cleaner version of the same figure with only significant results in Appendix XXV. Of these 120 hazard ratios, 16 are significant results. Some of the significant results have very large confidence intervals, suggesting that there are not enough observations to estimate possible effects with a precision that is interpretable.

Firms with investment instruments have a higher probability of transitioning from the not innovative state to the supplier based strategy. This is exactly the change that should follow based on supported activities. Firms with investment instruments also have a smaller probability of shifting from a supplier based strategy to the not innovative state, meaning that this type of instrument is also linked with increases in innovation persistency for supplier based strategies. Firms with investment instruments also have a smaller probability of transitioning from market oriented strategies to internal strategies.

Firms with innovation and R&D instruments have a higher probability to transition from the not innovative state, from internal strategy and from the market

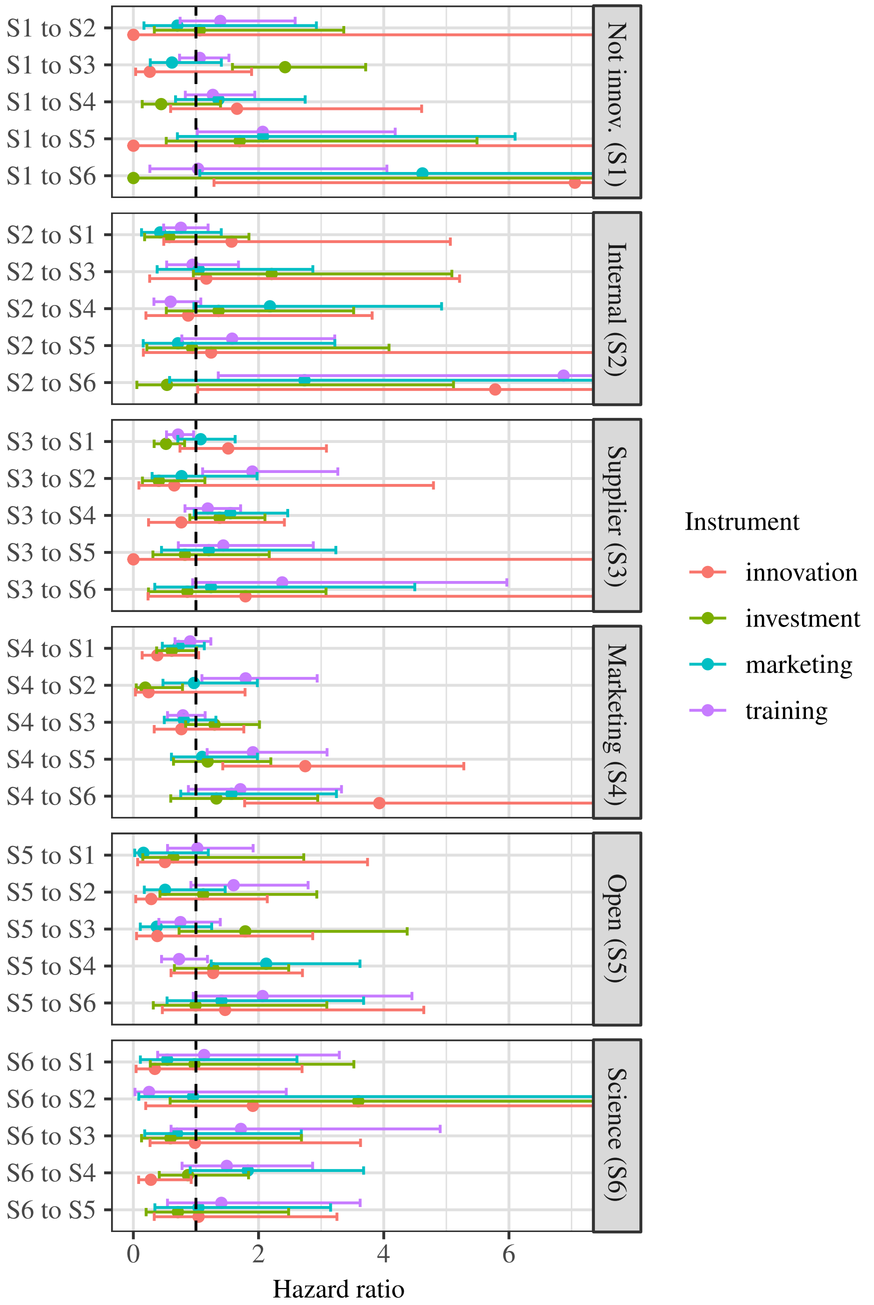

Figure 9.5: Hazard ratios for innovation policy instruments in the six-state Markov model with full dataset and exact transitions.

oriented strategies to the science based strategies. Since not innovative and internal strategy estimates to the science based have very large confidence intervals, these results should be interpreted with caution. However, results suggest that innovation and R&D instruments are also linked with a higher probability of transitioning from the market oriented strategy to the science based strategy with four times larger probabilities and a lower probability of transitioning from a science based to market oriented strategy a bit less than four times. Firms with innovation and R&D instruments also have a higher probability of transitioning from market oriented strategy to the open innovation strategy, suggesting that this instrument type captures some activities beyond R&D activities as well.

Firms with marketing and export promotion instruments have a higher probability of transitioning from a not innovative state to the science based strategy. However, as mentioned already, the shift from not innovative to science based is observed so rarely that all effects have very large confidence intervals. Firms with marketing and export promotion instruments have a higher probability of transitioning from open innovation strategies to market oriented strategies. This result suggests that firms are able to reduce their partnerships when they are participants of this instrument type. However, it remains unclear whether this shift is positive in general, as shifting from complex to simple innovation strategies might not be a desired result. It might be possible that these shifts align with some specific period in the firm's product life-cycle, described in Chapter 2. For example, when earlier product development efforts needed the input from many partners and the firm is slowly shifting towards more cost-based strategies to maximise profits. Turning from open innovation strategies to marketing based strategies aligns with this attitude.

Firms with training and skills development instruments have a higher probability of transitioning from not innovative state to open innovation strategy. Firms with training instruments also have a higher probability of transitioning from the market oriented strategy to open innovation. However, there are also results suggesting training instruments are linked with higher probabilities of transitioning to an internal strategy as well. These might not be the shifts that are intended, especially for more complex strategies.

Firms with training and skills development instruments have a lower probability of transitioning from a supplier based strategy to the not innovative state. This, alongside with investment instruments, suggests that some instruments can keep firms from becoming not innovative. If these effects are compounding, then it might be possible to reduce probabilities of firms transitioning to the not innovative state to very low levels. This raises the question of whether these effects are necessary and how firms would react. It seems that it would be an ideal case for cost displacement to public funds.

The results here are more complex than presented in Chapter 8. With Markov models, the effects of innovation policy instruments are a lot less significant than with multinomial models. At the same time, Markov models are better for taking the complexity of dynamics of innovation strategies into account. The results here and from previous chapters also suggest that some innovation instruments are positively linked with shifts between strategies. Results from Markov models and multinomial models presented in the last chapters point towards similar directions. Investment instruments lead to supplier based strategies and innovation and R&D instruments lead to science based strategies. However, the dynamics suggest that this is not a straightforward path, and firms are not easily jumping from not innovative state to complex innovation strategies.

To show the possible effect of innovation policy instruments, there are three sets of probability matrices in Appendix XXVI. These matrices show probabilities estimated based on the three-state Markov model with the full dataset and exact transitions in different time periods. Since transition intensities estimate the instantaneous risk, it might be better to look at probabilities in a given period. Matrices show the probability of transitioning from and to any state in two years, six years and ten years. The first set shows the probability for any firm without any innovation policy instruments; the second set with innovation and R&D and training and skills development instruments given only on years three and four; and the third set with firms participating in the treatment every year. The last is an approximation if the effect of the treatment in the first year would be fully absorbed by the firm and would cumulatively add to its performance or choice of strategy every year.

These probability matrices show that firms are not very likely to take up complex innovation strategies in a very short time. However, in ten years, the probabilities are a bit higher than over shorter periods. The models estimate that, if given more time, firms step out of the not innovative state at some point. However, the likelihood of remaining in the original state is smaller with each passing period. Therefore, Markov models suggest that firms end up shifting from their original strategies more often than not, except for not innovative firms. Even in ten years, there is about a 58 percent probability that if a firm started as not innovative, it will stay that way.

The second set shows probability matrices for firms that received innovation and R&D instruments and training and skills development instruments in years three and four. These are simulated results based on the Markov model. The first probability matrix at year two is same as before, since the firms are not treated. At year six, a few years after the treatment, firms are much more likely to end up in complex strategies compared to the non-treated group. However, the effect largely wears off by year ten, where the probabilities of ending up in complex innovation strategies are not very different from the non-treated group. Results here show that with Markov models, the effect of treatment is not persistent. If it is assumed that treatment wears off for firms, e.g. it is only monetary without any learning effects, then long-term results will not change much.

The third set shows probability matrices for firms that received innovation and R&D instruments and training and skills development instruments every year in this ten year period. These are also simulated results based on the Markov model. The assumption here is that the treatment effect of instruments is persistent, i.e. firms participating in instruments absorb this new knowledge or other effects in full, and these persist in the firms for the whole simulated period.

The effects of just these two instruments would be quite large in this case. The not innovative state is no longer the most likely state for any group. Also, the probabilities of taking up or staying in complex innovation strategies are at least four times larger than for other simulated sets.

It seems that it matters a lot if firms only participate in instruments which shift their innovation strategies at some point, or if the effects of these shifts are persistent for firms. This begs the question of whether the change in firm behaviour is permanent when they participate in instruments. Unfortunately, this question can not be answered sufficiently with the models presented here.

There are $4 \times 4 = 16$ combinations of probability matrices available for simulating with the covariates used here. The example in Appendix XXVI shows just one for brevity and illustration.

This chapter introduced multi-state Markov models for estimating the dynamics of firm innovation strategies. Results from this chapter and previous estimations are analysed and explained in the Discussion section of the thesis.

10. DISCUSSION & CONCLUSION

10.1. Discussion

The main findings of this thesis will be discussed in a slightly different order compared to first appearance in the main text. I have classified Estonian public support to firms into a taxonomy for use in empirical modelling. The analysis of participation rates in policy instruments revealed two important themes.

First, there is plenty of variety in supported activities. Almost all possible elements of the innovation process within the firm have some policy instruments targeted towards them. Yet, in most EU countries, policy mixes are a result of incremental extension of instruments rather than a deliberate result of policy design (Nauwelaers et al., 2009). A policy mix *per se* is not the goal, but rather a coordinated set of instruments to tackle complex issues while taking their possible interactions into account. It has already been noted in Estonia that a lack of coordination in governance is a threat to realising policy goals, even though there is a broad set of instruments supporting R&D and innovation (Männik, 2007). Considering future plans, the next Estonian R&D, innovation and entrepreneurship strategy is a joint work between the Ministry of Education and Research and Ministry of Economic Affairs and Communications[1]. This is a step forward in policy-making. However, R&D and innovation issues in regards to agriculture or environmental issues still remain in separate domains.

With variety, there are possible interaction effects between policy instruments. There are already some attempts to investigate and disentangle the possible mechanisms of the policy mix (e.g. see Cunningham, Edler, et al. (2016) and Flanagan et al. (2011)). With the data and taxonomy created in this thesis, it was possible to show that, indeed, there are a lot of occurrences of simultaneous use of policy instruments (see Chapter 4.2). Cunningham, Edler, et al. (2016, p. 531) bring out the complexity involved succinctly: "*The most problematic issues for quantitative analysis of interplay concern interactions over time and system complexity. The data required to establish causality and sequentiality over time, in the face of random external events, can be excessively challenging.*"

I would like to point out that the descriptive statistics provided in this thesis make up one of the first examples of providing evidence of the policy mix in such wide

[1] There are only draft documents currently, but it will be available sometime in spring 2020 and the strategy is in place until 2035. This will be a longer period compared to previous separate strategies in R&D and entrepreneurship covering seven year intervals.

categories of policy instruments on the firm level. Data gathered in this thesis provides a comprehensive overview of all policy instruments where firms could participate. Evidence provided here shows that, indeed, the possibility of interaction and interplay is high, and the policy mix needs further investigation as a very relevant concept in policy analysis. Most studies tend to take only one instrument into account (Martin, 2016), but there are some rare exceptions, e.g. Guerzoni and Raiteri (2015) and Hottenrott et al. (2017). This is especially relevant for empirical investigations, since without checking for treatment from other instruments, possible effects of cross-treatment can create bias in the results.

One caveat in this thesis is that EU level innovation policy instruments are not included in the data. These include direct business support from the Framework Programmes for Research and Technological Development, colloquially known as framework programmes. Recent framework programmes have been named as well: Horizon 2020 is within the period from 2014 to 2020; the latest, Horizon Europe starts from 2021 and lasts until 2027. Data in this thesis covers the periods of the sixth (2002-2006) and seventh (2007-2013) framework programmes.

Similarly, the CIS does not cover all economic activities equally. Some major omitted economic activities are agriculture, forestry, construction, parts of retail, hospitality, real estate, some creative industries, and some health-care industries. Even though the CIS is representative of the population in its industries, it does not cover the whole range of economic activities we see in society. The results discussed here should take this into account.

Descriptive statistics in Chapter 5 showed some discrepancies between externally added data about use of policy instruments and what was surveyed in the CIS. There is a general question in the CIS about the use of policy instruments without any added detail. Still, there is a large gap on what was reported and what can be shown with external data. It seems that firms underreport the use of policy instruments heavily in the CIS. Studies, such as Czarnitzki and Delanote (2015) and Szczygielski et al. (2017), depend only on the CIS survey to investigate the possible effects of policy instruments. Descriptives shown in this thesis indicate that they might seriously understate the role of policy instruments when no external data is used.

Researchers rely on CIS data anonymously by national statistics offices to protect the respondents. However, some further investigation into underreporting of policy instruments is warranted in the future. Whether it is because firms feel that some policy instruments are not relevant or unrelated to any innovative activities is currently unknown.

The taxonomy created in this thesis covers many different policy fields, at least when viewed from the governing side. Thus, the instruments included fall under many different ministries. However, firms have no fealty to any ministry. There is a further need for better coordination between policies and ministries. As mentioned, the next strategic plan for entrepreneurship, R&D and innovation is joint work between two ministries. Still, innovation policy is wider in scope, and even this strategic plan leaves agriculture, energy and many other economic activities out in full.

The complexity of the policy mix is also wider than what was analysed in this thesis. The interplay between direct support to business, regulations, tax systems and more, all influence innovativeness in firms. There are positive steps towards better coordination, but there is still much more to do.

The relationship between policy instruments as an input to innovative activities and innovations as outputs is varied. Policy instruments support certain activities, such as developing marketing plans or co-financing investments in new machinery. The innovation processes described by policy instruments included in this thesis are shown in Chapter 3.5. It is to be expected that these instruments can yield different results.

The results of this thesis show that, in general, policy instruments demonstrate the expected output behaviour. For example, there is a positive relationship between instruments that support R&D and the creation of new products and services, but not with new processes. However, some policy instruments such as consulting, financial guarantees and labour support instruments have no significant relationship with any innovation output. This is relevant to policy makers and analysts when evaluating the efficacy of STI policies in general. If we do not see any significant relationship with innovation outputs while taking other possible policy instruments into account, are these instruments justifiable as a public expense?

The analysis in this thesis showed that the variety in the input-output relationship between STI policies and innovation outputs should be taken into account. Nevertheless, expectations from policy instruments should be differentiated into finer detail than just being innovative. If wider taxonomies of policy instruments are used in empirical analyses, there is a possibility for misinterpretation of results. A more positive aspect is that most categories of STI policies did indeed show a positive relationship with innovation outputs. Even though the results in this thesis cannot prove a causal relationship, they still point away from the most bleak conclusions.

There are five distinct innovation strategies visible for Estonian firms. These are supplier based, market oriented, open innovation, science based and internal strategies (see Chapter 6). Many of the characteristics already described in the original Pavitt's taxonomy (Pavitt, 1984; Pavitt et al., 1989) can be seen here, showing how versatile this taxonomy really is.

Review of the literature revealed comparable estimations from Denmark (Jensen et al., 2007; Leiponen and Drejer, 2007), Finland (Leiponen and Drejer, 2007), Sweden (Sellenthin and Hommen, 2002), Spain (Camacho and Rodriguez, 2008), Netherlands (De Jong and Marsili, 2006; Marsili and Verspagen, 2002), Switzerland (Hollenstein, 2003, 2018), UK (Battisti and Stoneman, 2010; Pavitt, 1984; Pavitt et al., 1989) EU wide (Castellacci, 2008; Frenz and Lambert, 2012; Srholec and Verspagen, 2008). Nevertheless, differences in estimation methods and variables considered make comparisons between results from other countries difficult (Frenz and Lambert, 2012). Some similarities can be pointed out. The science based cluster is very small in Estonia, totalling about 6% of all observations. However, Scandinavian countries report between 15 and 21 percent of the population (Leiponen and Drejer, 2007), Switzerland around 18 percent (Hollenstein, 2018), Netherlands around 25 percent among SMEs (De Jong and Marsili, 2006), and Spain around 15 percent (Camacho and Rodriguez, 2008). Unfortunately, there are not many studies among other Central and Eastern European countries that can be used for comparison. If this finding is not an artefact of incomparable methods, it could explain some of the gap in value added between Estonia and other Western European countries. There are just not enough firms with R&D based strategies for innovation in Estonia. Mürk and Kalvet (2015) gave an overview of firms that report R&D activities in Estonia. The whole population totals about 250 firms. Over the 10 years of CIS data used in this thesis, about 200 firms with science based innovation strategies were identified, an example of the permeating effect of industrially representative nation-wide sampling in small countries.

Another contrasting aspect of Estonian firms is their reliance on supplier based innovation strategies. Here, contrarily, the group of firms is larger than in other comparable European studies. In Estonia, this is about a third of all observations. In other countries, it seems to be one of the smaller groups (De Jong and Marsili, 2006; Leiponen and Drejer, 2007). Supplier based innovation strategies are linked with lower opportunities and lower innovative outputs than other strategies (Castellacci, 2008; Pavitt, 1984).

One distinguishing characteristic of Estonian firms seems to be the existence of an internal innovation strategy. This moderately sized group of firms with distinct innovative activities, mostly relies on within group exchange of information and cooperation with external training and acquisition of machinery. Data added after estimation revealed that more than 99 percent of firms in this category are part of a group. Regrettably, other studies have not included descriptive statistics about firm ownership in their papers. Foreign ownership is an important source of technology for small countries, a mechanism for technology transfer (Keller, 2004). In addition, there is evidence that foreign ownership differs in management techniques, mostly with higher quality (Bloom and Van Reenen, 2007). However, firms in Central and Eastern Europe tend to have more subsidiary relationships towards parent companies. Those which are considered high-tech and R&D intensive, tend to only be production facilities in reality (Havas, 2005; Radošević, 2002). A question of mandate and local independence remains.

Previous investigations with similar objectives were exclusively done with cross-sectional data. To my knowledge, there has been only one study with panel data so far, such as in this thesis. Hollenstein (2018) analyses innovative behaviour with Swiss data — also innovation survey results, but not harmonised with the CIS, so the results are not exactly comparable. Still, some results from the Swiss analysis on the dynamics of innovation strategies are similar.

Dynamics of firm innovation strategies showed that firms are able to shift their innovation strategies often and in relatively short time periods. This means that firms are able to reorient their choices while doing innovative activities within a few years. These could be their potential cooperation partners, sources of new knowledge, other inputs like machinery or training, and so forth. Hollenstein, 2018 describes this as a necessity for Swiss firms, due their highly advanced and competitive environment, and views this as external confirmatory evidence of his results. I do not believe that the same argument could be applied in full to the competitive environment where Estonian firms operate. Estonian firms on average are laggards by every measurable dimension to Swiss firms (see the regional EU innovation scoreboard for comparison of a compendium of indicators by Hollanders, Es-Sadki, and Merkelbach (2019)). Yet, the dynamics of innovation strategies show strikingly similar behaviour.

I consider results from the Hollenstein (2018) paper as a confirmation that the results here are credible. However, I disagree on the mechanisms that drive this behaviour. To sum up this argument, evidence from multiple firm-level studies show that firms often change or reorient their innovation strategies within short time frames. This is a combination of their choices while doing innovative activities, showing that firms are able to switch to an appropriate strategy relatively quickly (within a few years). Unfortunately, there is no clear explanation about what the drivers of these shifts may be. It is possibly a combination of changes in both the external environment (market demand, response to competition, legal environment, etc) and internal choices (market choices, capabilities, resource availability, etc) (Geels and Schot, 2007; Poel, 2003). Disentangling this combination on the firm-level is a challenge in itself.

The results of this thesis indicate that some capabilities are harder for firms to obtain than others. Shifts between strategies happen more often between those that rely less on R&D capabilities. If firms develop these capabilities once, then they are more likely to rely upon R&D based strategies more often in the future as well. Results show that persistence of different strategies is not uniform. One explanation is that it depends on the type of costs associated with attaining these strategies (Ganter and Hecker, 2013). Unfortunately, the true costs of shifting between strategies are unobserved in the data. Still, it can be assumed that to rely more heavily on R&D requires more high-skilled personnel, even if R&D itself is outsourced. There are different types of R&D investment which can have different returns on investment (Cassiman et al., 2002; Griffith et al., 2004). Firms' internal capabilities need to be able to appropriate this inflow of knowledge (Cohen and Levinthal, 1990). Mean sojourn times for different strategies show that many of the cooperative relationships and behavioural rigidity cannot be assumed to persist over time. It takes more time to develop complex innovation strategies, and, when these strategies are developed, firms are more likely to stay innovative for the next period as well.

The results of this thesis also suggest that there is little interchangeability between R&D based innovation strategies and open innovation strategies. Firms that develop either rather transition to some other innovation strategies than between these two complex innovation strategies. Conditions for choosing either a make-it-yourself or a buy-in strategy depend both on firm size and capabilities (Veugelers and Cassiman, 1999), market conditions (Cruz-Cázares et al., 2013), organisational structure and ownership (Cefis and Triguero, 2016), and appropriation conditions (Drechsler and Natter, 2012). Heavy dependance on partners for core products can be a risky strategy (Fine and Whitney, 1996). In the Estonian case, firms seem to embrace either science based or open innovation strategies but do not move from one to another often, suggesting that these two innovation strategies are not on a continuum of strategy evolution.

Finally, the relationship between policy instruments and firm innovation strategies show some credible relationships. Only investment, R&D and innovation, marketing and export promotion, and training and skills development instruments were modelled because they showed the most potential in Chapters 7 and 8. At the more detailed level with five different innovation strategies, Markov models show only a handful of statistically significant relationships out of 120 tested.

It is evident that there are inconsistencies in proposed dynamics of innovation strategies for different policy instruments. In addition, there are also separate layers of results depending on whether different policy instruments are compared or the mechanism of dynamics is under investigation.

The results of this thesis suggest that policy instruments do not increase the probability of a firm attaining complex innovation strategies if they have been not innovative before. Suggesting that there are so-called learning effects within the firm, firms learn to walk before they learn to run. Learning from previous R&D experience and from collaborations on previous projects leads to better management of innovation strategies (Clarysse et al., 2009). Innovation policy instruments might increase this learning process (Autio et al., 2008).

These results imply that if innovation policy encourages firms to take up more complex innovation strategies like open innovation and science based strategies, the target audience is firms with some experience in creating innovations beforehand. These can be firms with more simple innovation strategies, such as supplier based or internal strategies.

Results indicate that reaching complex innovation strategies can be a step-wise process. First, firms reach simpler innovation strategies and then more complex ones. Results also indicate that policy instruments that might increase the probability of transitioning to these innovation strategies differ for simple and complex strategies.

Policy instruments that support innovation activities, i.e. they finance the creation of new products or services and provide support for R&D activities, also show the highest probability for the firm to take up a science based innovation strategy. However, results from Markov models suggest that this is only relevant for firms that already have simpler innovation strategies. Firms are more than twice as likely to take up complex innovation strategies if they already have simple innovation strategies when they are part of R&D and innovation instruments.

Results from different OECD countries also indicate that, without R&D policy instruments, a significant share of firms would not initialise R&D activities (OECD, 2006). This relationship might exist also for R&D tax credits (Neicu et al., 2016). To promote more complex innovation strategies, direct R&D promotion efforts might be better allocated to firms with some experience, but not to already R&D intensive firms (Wanzenböck et al., 2013). In addition, results in Chapter 9 suggest that R&D and innovation instruments keep firms from transitioning out from science based strategies.

There is some evidence that R&D subsidies can also induce firms to take up more cooperative strategies among SMEs in EU peripheral areas (Orlic et al., 2019). Results in this thesis also suggest that R&D and innovation policy instruments increase the probability of transitioning from market based strategies to open innovation strategies. However, similar results were not relevant from any other innovation strategy.

Investment instruments are usually combined with R&D and other innovation policy instruments in analysis (Cunningham, Gök, et al., 2016). In Estonia, they have been so influential that they merit a separate category. Investment instruments have been relevant for technology catch-up and usually do not include any R&D funding whatsoever (see Chapter 3). These instruments are meant for acquiring new machinery or other forms of physical capital, with some part co-financed by the state.

Results indicate that firms with investment instruments are 50 percent more likely to transition from the not innovative state to simple innovation strategies. Results suggest that they are more likely to have a supplier based innovation strategy. The results also indicate that firms do not have more complex innovation strategies afterwards. Firms that participate in investment instruments do not exhibit any additional strategic behaviour besides the one directly funded, i.e. acquiring machinery or technology from suppliers. These results indicate that, at the very least, the supported behaviour is observed for the firms. However, nothing additional is detected. Therefore, investment instruments might be a good start for firms who otherwise would have no innovative activities whatsoever. It is difficult to estimate the return on investment for these instruments, but if some of these firms go from simple innovation strategies to more complex ones later, it might have a cascading effect.

Previous research suggests that business advisory services, such as programmes for managers to enhance their skills, marketing advisory, export planning, and technology advisory services are beneficial to firm outcomes (Cumming and Fischer, 2012; Shapira and Youtie, 2016). Marketing capabilities are fundamental to firm innovation strategy (Weerawardena, 2003). Firms with marketing and export promotion instruments also show higher rates of innovativeness in this thesis. However, firms with marketing and export promotion programmes showed very little relationship with shifting their innovation strategies. Evidence from other countries shows that SMEs themselves find benefits from business advisory services, yet marketing and export planning are not the most sought after (Boter and Lundström, 2005).

There are reports from other countries showing that publicly offered business advisory services have a very low uptake (Boter and Lundström, 2005; Curran, 2000). This is not observed in the case for Estonia. Marketing and export promotion programs, along with consulting and other possible business advisory services are among the more widely used policy instruments (see Chapter 5). Curran and Blackburn (2000) bring out several reasons for low uptake of business services, such as low confidence of the supplier, lack of awareness, high prices, mismatch with demand, and lack of quality. The Estonian case shows that use of policy instruments similar to business advisory services have seen an upward trend, at least in the sample under analysis in this thesis, indicating that firms see at least some value in such services. Uptake itself is no measure for quality or fulfilment of policy objectives (Storey, 2008)

Training and skill development policy instruments show a positive relationship with transitioning from simple to complex innovation strategies. However, the results are not totally uniform when estimated at a finer level for all five strategies together. There seems to be a positive relationship with keeping firms from not transitioning to the not innovative state, i.e. keeping them innovative longer.

Competences and skill development itself is a vital part of innovation policy, and most economies have deficiencies in the level of competences and a too short perspective on reconciling them (Borrás and Edquist, 2015). An overview of recent research highlights three findings on the relationship between training and skill development and innovativeness (Jones and Grimshaw, 2016): first, there seems to be a positive relationship between skill development and innovativeness; second, organisations benefit from developing their internal knowledge pool; and third, a mix of different skills is needed. Results of this thesis also show a positive relationship between training and skill development instruments and firm innovativeness. However, these are most likely biased upwards. If these instruments also help firms to attain more complex innovation strategies and to refrain from becoming not innovative, they merit their place in the policy mix in Estonia.

10.2. Limitations

The research done in this thesis must be considered with taking some limitations into account. Limitations are based on the methods and data chosen to carry out this research.

The true question in policy evaluation is about how firms would behave if they had not received any intervention. Unfortunately, we can not observe this case because there are no do-overs with firms. Therefore, the only possibility is to compare firms that received some intervention with firms that did not. If these two groups are different from each other in any way, besides the intervention itself, the effect of policy intervention is difficult to estimate. Common estimation techniques are biased in this case (see Chapter 7.3 for a lengthier description of this issue).

The methods used in this thesis do not fully overcome the issues of selection bias. There is a trade off in how wide the scope is with policy analysis and how carefully the identification method can be constructed. In this thesis, I have opted to analyse a wide range of different policy instruments in a single setting, which in turn has reduced the possible methods available. Due to these limitations, true causal effects of policy intervention to output or behavioural additionality are not known.

Data used in this thesis is collected on the firm level. However, many innovation strategies can be on the product level. Firms have multiple products concurrently in production, with different time horizons, different innovative activities involved, and different strategies. Some are more experimental, user-driven innovations with more radical innovation based strategies, and some are so-called cash cows with only incremental improvements and cost-cutting strategies.

In this thesis, firms received a single strategy as their pattern of innovation to characterise their whole behaviour. Even though this pattern of innovation was a combination of different activities, it still cannot differentiate between product lines. Therefore, for some firms, there may be more shifts within the firm than it is possible to observe with the data provided. Product level and firm level data should be collected for the same firms at some point to compare their possible outcomes. Unfortunately, there are no large-scale surveys that collect information about innovative activities on the product level available.

There are also some gaps in the data about innovative activities. CIS data has been provided by Statistics Estonia, and they assure it is representative of the population of Estonian firms in every period. Gaps originate from two main mechanisms. First, some firms just go out of business. Second, some firms choose not to reply in every period[2]. These gaps create an unbalanced panel which might create some problems with representability if omissions are not random. Since the CIS is confidential, I cannot verify with firms directly why they are not represented in some periods and cannot ask these questions from them directly. This limitation is acknowledged.

10.3. Future work

Several possible further research paths are available. I would like to divide them into two different sets - policy instruments and dynamics of innovation strategies.

With policy instruments, the most interesting questions raised in this thesis deal with the policy mix. The data gathered for this thesis have opened up a possibility to investigate firms based on *all* instruments where they have been beneficiaries. There is a lack of firm level studies where the innovation policy instrument mix is larger than only R&D, as it was here (Cunningham, Edler, et al., 2016). Therefore, one possibility is to start disentangling the policy mix to see what types of interaction effects exist, whether policy instruments and their combinations support or hinder each other, create synergy or are independent. One may also question whether a *right* combination in the policy mix exists that maximises innovativeness in the innovation system.

With dynamics of innovation strategies, there should be further investigation of the shifts. In this thesis, the main investigation was whether policy instruments are one driver. However, a more widespread research to pick apart firm specific and

[2] My conversations with officials at the Statistics Estonia lead me to believe that they send the survey to all possible candidates.

industry specific effects should be of interest — whether innovation policy should be at the industry or firm level in its design. Similarly, exogenous shocks are of interest. The role of business cycles for innovation strategies is one example. The model presented in this thesis is a good starting point to pick apart these challenges.

10.4. Conclusion

The main theme of this thesis was to investigate whether firms change their innovation strategies when they receive public support for executing certain strategies. From this question of interest, the main aim was put forward as *to estimate the possible effects of STI policy instruments on firm innovation strategy*.

To fulfil this aim, several research questions have been proposed. I will not reiterate them all in full, but will describe the cumulative nature of this thesis. I showed how the innovation process can be modelled within the firm; what are the possible justifications for interventions and instruments with which the public sector can support firms; how firm innovation strategies reorient over time; how public support instruments are related with firm-level innovation outputs; and finally, how public support instruments are related with firm-level changes in innovation strategies.

This thesis aimed to connect two themes, one dealing with patterns of innovations for firms and the other with possible effects of STI policies. Patterns of innovation are a summary of firms' strategic and operational choices for activities while creating innovations. These are choices such as: what kind of inputs to purchase for innovative activities; if and what partnerships to form; what type of appropriation methods are used for intellectual property; and so forth. A combination of these choices forms the innovation strategy.

The main aim of this thesis was to analyse the relationship between innovation policy support to firms and how it might change their innovation strategies. Data for estimations comes from Estonia between 2002 and 2012.

STI policy instruments have been categorised into a taxonomy. There are ten different kinds of policy instruments available for firms as direct business support. These are support for R&D and innovation, investments, collaboration programmes, consulting, direct subsidies, financial guarantees & sureties, labour support, marketing & export promotion support, training & skills development support, and mixed support. Some of these policy instruments have been more popular and important than others. For example, investment support, R&D and innovation support, marketing & export promotion, and training & skills development support have been more closely related with innovative firms. In the end, these instruments were under closer investigation as well.

The results of this thesis indicate that firms are quick to react with changes in their innovation strategies. It follows that they are able to quickly deploy their capabilities or create new ones to fulfil some goals. Firms can change their innovation strategies often and in a relatively short time, over a few years. These results suggest that STI policy can also expect rapid changes from firms if proper stimuli is applied.

In addition, there is a step-wise logic to changes in innovation strategies. Not innovative firms develop simple innovation strategies first and more complex ones later. It takes time, experience and learning to develop and fulfil complex innovation strategies. These results suggest that STI policies should also adapt to the proper target audience. Leap-frogging might have limits if firms are very inexperienced.

Finally, some STI policy instruments do show a positive relationship with changes in innovation strategies. Firms with investment instruments are more likely to take up simple innovation strategies based on supplier relationships. Firms with R&D and innovation instruments are more likely to take up more complex innovation strategies, based on cooperation with research facilities and universities and with more open innovation overall. Firms with training and skill development instruments are less likely to stop being innovative at all.

It seems that many of the relationships and activities that STI policies wish to promote can be seen in firms' activities and in their strategies. However, how lasting these effects are needs more scrutiny in the future. Results here suggest that policy instruments can be demanding for firms. Innovation policy instruments should be challenging enough to create strategies that we wish to promote in the innovation system — cooperative, open and R&D intensive — for they will create capabilities that persist.

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Appendices

I. List of instruments classified in taxonomy

List of all instruments classified in taxonomy of innovation policy instruments

Policy instrument	Paying agency	Instrument type in taxonomy
7. raamprogrammi ja COST koostöövõrgustiku projektide ettevalmistustoetus	SA Archimedes	Collaboration programmes
7. raamprogrammi ja COST koostöövõrgustiku projektide ettevalmistustoetus	SA Eesti Teadusagentuur	Collaboration programmes
Eesti - Läti programm 2007-2013 – rahvusvaheline teaduskoostöö arendamine	Siseministeerium	Collaboration programmes
Kesk-Läänemere INTERREG IV A programm 2007-2013 Lõuna-Soome ja Eesti allprogramm – reovee süsteemide arendamine	Siseministeerium	Collaboration programmes
Meede 1.9 - Tootjarühma loomine ja arendamine	PRIA	Collaboration programmes
Arendustöötajate kaasamise toetus	EAS	Consulting
Ettevõtlus- ning innovatsioonialaste teadmiste ja oskuste ning teadlikkuse arendamise programm	EAS	Consulting
Postiteenused – hüvitis üle-Eestiliste perioodiliste väljaannete edastamise eest	Majandus- ja Kommunikatsiooniministeerium	Direct subsidy
Päästmisabi	Rahandusministeerium	Direct subsidy
Toetusskeemide muutmise tõttu saamata jäänud tulu hüvitamine	Maaelu Edendamise SA	Direct subsidy
Ümberkorraldusabi	Majandus- ja Kommunikatsiooniministeerium	Direct subsidy
Ettevõtjate laenukapitali kättesaadavuse parandamise täiendav tugiprogramm	SA KredEx	Financial instrument (loans and guarantees)
Ettevõtluse laenude ja pangagarantii käendus	SA KredEx	Financial instrument (loans and guarantees)

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
Ettevõtluslaenude riiklike tagatiste ja kapitalilaenu programm	SA KredEx	Financial instrument (loans and guarantees)
VKE investeerimislaenude käendamine	SA KredEx	Financial instrument (loans and guarantees)
Vähese tähtsusega abi tagatise vormis	Maaelu Edendamise SA	Financial instrument (loans and guarantees)
Eesti filmi toetuskava - EFSA	Eesti Filmi SA	Innovation & R&D
Filmikunsti toetusprogramm - Kultuuriministeerium	Kultuuriministeerium	Innovation & R&D
Innovatsiooniosakute toetusmeede	EAS	Innovation & R&D
Innovatsiooniteadlikkuse programm, eeltaotlus	EAS	Innovation & R&D
Keskkonnaprogramm	SA Keskkonnainvesteeringute Keskus	Innovation & R&D
Klastriprojektide kaasfinantseerimise toetus	Tallinna Ettevõtlusamet	Innovation & R&D
Klastrite arendamise toetus	EAS	Innovation & R&D
Laevandustoetus Eesti lipu all sõitvatele kaubalaevadele	EAS	Innovation & R&D
LEADER (projektid) III telg	PRIA	Innovation & R&D
Meede 1.1.2 - Maakondlikud tegevused	PRIA	Innovation & R&D
Teadus- ja arendustegevuse projektide toetamise programm, eeluuring	EAS	Innovation & R&D
Teadus- ja arendustegevuse projektide toetamise programm, rakendusuuring	EAS	Innovation & R&D
Teadus- ja arendustegevuse projektide toetus	EAS	Innovation & R&D
Teadus- ja arendustegevuse projektide toetus, rakendusuuring	EAS	Innovation & R&D
Teadus- ja arendustegevuse projektide toetus	SA Archimedes	Innovation & R&D
Teadus- ja arendustegevuste projektide toetamine	EAS	Innovation & R&D

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
2.1.1 Veemajanduse infrastruktuuri arendamine	SA Keskkonnainvesteeringute Keskus	Investment
2.1.2 Nõuetele mittevastavate tavajäätmeprügilate sulgemine	SA Keskkonnainvesteeringute Keskus	Investment
2.1.7 Ladestusalaga jäätmekäitluskeskuste ladestusala laiendamine	SA Keskkonnainvesteeringute Keskus	Investment
3.2.3 Teadusaparatuuri ja -seadmete kaasajastamine	SA Archimedes	Investment
3.3.1 Transpordi infrastruktuuri arendamine (ÜF)	Tehnilise Järelevalve Amet	Investment
3.4.1 Transpordi infrastruktuuri arendamine (ERDF)	Aktsiaselts Tallinna Lennujaam	Investment
3.4.1 Transpordi infrastruktuuri arendamine (ERDF)	Tehnilise Järelevalve Amet	Investment
4.1 Transpordi infrastruktuuri arendamine	Aktsiaselts Tallinna Lennujaam	Investment
4.1 Transpordi infrastruktuuri arendamine	Tehnilise Järelevalve Amet	Investment
4.1 Transpordi infrastruktuuri arendamine	Veeteede Amet	Investment
4.2 Keskkonna-infrastruktuur	SA Keskkonnainvesteeringute Keskus	Investment
Alameede 3.11.1 - Kala ja vesiviljelussaaduste töötlemise toetus	PRIA	Investment
Alameede 3.11.3 - Kalasadamate moderniseerimine	PRIA	Investment
Elektriautode toetus	SA KredEx	Investment
Energia säästmiseks antav investeerimisabi	Rahandusministeerium	Investment
Ettevõtluse infrastruktuuri arendamise toetus	EAS	Investment
Euroopa Majanduspiirkonna finantsmehhanismist ja Norra finantsmehhanismist antav vähese tähtsusega abi	Rahandusministeerium	Investment

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
Jäätmete kogumise, sortimise ja taaskasutusse suunamise arendamine	SA Keskkonnainvesteeringute Keskus	Investment
Katse- ja pooltööstuslike laborite infrastruktuuri investeeringute toetamine	EAS	Investment
Keskkonnakasutusest riigieelarvesse laekunud rahast regionaalabi andmise tingimused	SA Keskkonnainvesteeringute Keskus	Investment
Keskkonnatasude seaduse § 19 lg 5 alusel antav vabastus saastetasu maksmisest süsinikdioksiidi heitmete eest	Keskkonnaministeerium	Investment
Meede 1.4.2 - Investeeringud loomakasvatusehitistesse	PRIA	Investment
Meede 1.5.1 - Metsa majandusliku väärtuse parandamine	PRIA	Investment
Meede 1.6.1 - Põllumajandustoodete ja mittepuiduliste metsasaaduste töötlemine	PRIA	Investment
Meede 1.6.2 - Piimandussektori ja mahepõllumajandustootmise kohandumine uute väljakutsetega ning põllumajandustoodete ühise töötlemise edendamine	PRIA	Investment
Meede 1.7.1 - Põllumajandus- ja toidusektoris ning metsandussektoris uute toodete, töötlemisviiside ja tehnoloogiate arendamise alane koostöö	PRIA	Investment
Meede 1.8 - Põllu- ja metsamajanduse infrastruktuur	PRIA	Investment
Meede 2 - Põllumajandus- ja kalandustoodete tootmise ja turustamise parandamise toetus	PRIA	Investment
Meede 3 - Maapiirkondades alternatiivse majandusliku tegevuse arendamise ja mitmekesistamise investeeringutoetus	PRIA	Investment
Meede 3.1 - Majandustegevuse mitmekesistamine maapiirkonnas	PRIA	Investment
Meede 3.10 - Kalalaevastiku moderniseerimine ja uuendamine	PRIA	Investment

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
Meede 3.2 - Põllumajandustoodete töötlemise ja turustamise parandamise investeeringutoetus	PRIA	Investment
Meede 3.3 - Majandustegevuse mitmekesistamine maapiirkonnas	PRIA	Investment
Meede 4 - Maapiirkonna infrastruktuuri investeeringutoetus	PRIA	Investment
Meede 6 - Külade taastamise ja arendamise investeeringutoetus	PRIA	Investment
Metsanduse toetamise abikava	SA Erametsakeskus	Investment
Piirissaare ja Laaksaare sadamate rekonstrueerimine	Majandus- ja Kommunikatsiooniministeerium	Investment
Saastetasu asendamise regionaalabi kava	Keskkonnaministeerium	Investment
Taastuvenergiaallikate laialdasem kasutamine energia tootmiseks	SA Keskkonnainvesteeringute Keskus	Investment
Toetuskava elektrienergia tootmiseks taastuvenergia allikatest ja tõhusal koostootmisel	Elering AS	Investment
Tootmisettevõtete arendustoetus	EAS	Investment
Tööstusettevõtja tehnoloogiainvesteeringu toetus	EAS	Investment
Vooluveekogude seisundi parandamise tingimused	SA Keskkonnainvesteeringute Keskus	Investment
Väikelennujaamade dotatsioon	Majandus- ja Kommunikatsiooniministeerium	Investment
Väikesadamate toetamise toetusskeem	EAS	Investment
Alameede 3.8.2 - Nõuandetoetus	PRIA	Labour support
Ettevõtte praktikajuhendaja toetus	Tallinna Ettevõtlusamet	Labour support
Kvalifitseeritud tööjõu pakkumise suurendamine	SA INNOVE	Labour support
Palgatoetus ja puuetega ja pikaajalise tervisehäirega inimeste töötamise toetamine	Eesti Töötukassa	Labour support

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
Sotsiaalsete töökohtade loomise toetus	Tallinna Ettevõtlusamet	Labour support
Tööelu kvaliteedi parandamine	SA INNOVE	Labour support
Uute töökohtade loomise toetus	Tallinna Ettevõtlusamet	Labour support
Eesti kui reisisihi tuntuse suurendamise programm	EAS	Marketing
Ekspordi arendamise toetus	EAS	Marketing
Ekspordiplaani programm, elluviimine	EAS	Marketing
Ekspordiplaani programm, koostamine	EAS	Marketing
Eksporditurunduse toetus	EAS	Marketing
Messitoetus	Tallinna Ettevõtlusamet	Marketing
Riiklike turundusürituste programm	EAS	Marketing
Turismi turundustoetus ettevõtjale	EAS	Marketing
Turismiettevõtjate tootearenduse ja turunduse programm, tootearendus	EAS	Marketing
Turismiettevõtjate tootearenduse ja turunduse programm, turundus	EAS	Marketing
Turismitoodete arendamise väikeprojektide toetamine	EAS	Marketing
Välismessitoetus	EAS	Marketing
Ühisturunduse toetus	EAS	Marketing
Alustava ettevõtja stardi- ja kasvutoetus	EAS	Mixed support
Alustavate ettevõtjate starditoetus	EAS	Mixed support
Ettevõtlusinkubatsiooni programm	EAS	Mixed support
Stardi- ja kasvutoetuse programm	EAS	Mixed support
Uusi töökohti loovate ettevõtjate toetamine	Narva Linna Arenduse ja Ökonoomika Amet	Mixed support
Alameede "Kõrgkoolide ja ettevõtete koostöö"	SA Archimedes	Training
Ettevõtlus- ning innovatsioonialaste teadmiste ja oskuste ning teadlikkuse arendamise programm	EAS	Training

Continued.

Continuation of table.

Policy instrument	Paying agency	Instrument type in taxonomy
Koolituse programm, töötajate täiend- ja ümberõpe	EAS	Training
Koolitustoetuse programm	EAS	Training
Loomemajanduse tugistruktuuride toetus	EAS	Training
Meede 1.3.1 - Nõuandetoetus	PRIA	Training
Nõustamistoetus	EAS	Training
Nõustamistoetuse programm	EAS	Training
Teadmiste ja oskuste arendamise toetus	EAS	Training
Turismi teadlikkus- ja koolitusprogramm	EAS	Training

II. CIS panel data patterns

Data patterns

	Pattern	Firms	Percent	Cum. share of firms
1	2004 - 2006 - 2008 - 2010 - 2012	654	18.68%	18.68%
2	NA - NA - NA - NA - 2012	320	9.14%	27.81%
3	2004 - NA - NA - NA - NA	298	8.51%	36.32%
4	2004 - 2006 - NA - NA - NA	250	7.14%	43.46%
5	NA - NA - 2008 - NA - NA	242	6.91%	50.37%
6	2004 - 2006 - 2008 - NA - NA	210	6.00%	56.37%
7	NA - NA - 2008 - 2010 - 2012	182	5.20%	61.56%
8	NA - 2006 - NA - NA - NA	179	5.11%	66.68%
9	NA - 2006 - 2008 - 2010 - 2012	177	5.05%	71.73%
10	NA - NA - NA - 2010 - 2012	163	4.65%	76.38%
11	NA - NA - NA - 2010 - NA	154	4.40%	80.78%
12	2004 - 2006 - 2008 - 2010 - NA	135	3.85%	84.64%
13	NA - 2006 - 2008 - NA - NA	102	2.91%	87.55%
14	NA - NA - 2008 - 2010 - NA	68	1.94%	89.49%
15	NA - 2006 - 2008 - 2010 - NA	65	1.86%	91.35%
16	2004 - NA - 2008 - 2010 - 2012	48	1.37%	92.72%
17	NA - NA - 2008 - NA - 2012	41	1.17%	93.89%
18	2004 - 2006 - 2008 - NA - 2012	40	1.14%	95.03%
19	2004 - NA - 2008 - NA - NA	27	0.77%	95.80%
20	NA - 2006 - 2008 - NA - 2012	21	0.60%	96.40%
21	2004 - 2006 - NA - 2010 - 2012	18	0.51%	96.92%
22	2004 - 2006 - NA - 2010 - NA	18	0.51%	97.43%
23	NA - 2006 - NA - 2010 - NA	15	0.43%	97.86%
24	2004 - 2006 - NA - NA - 2012	14	0.40%	98.26%
25	NA - 2006 - NA - 2010 - 2012	14	0.40%	98.66%
26	NA - 2006 - NA - NA - 2012	12	0.34%	99.00%
27	2004 - NA - 2008 - 2010 - NA	8	0.23%	99.23%
28	2004 - NA - NA - 2010 - 2012	8	0.23%	99.46%
29	2004 - NA - NA - 2010 - NA	8	0.23%	99.69%
30	2004 - NA - 2008 - NA - 2012	6	0.17%	99.86%
31	2004 - NA - NA - NA - 2012	5	0.14%	100.00%

Source: Innovation Data (2018)

III. Paying agencies in Estonia

Paying agencies in Estonia with beneficiaries and total sum (2002 - 2012)

Paying agency	Instruments	Instrument types	Beneficiaries	Total sum
EAS	42	6	1239	170 243 554
Eesti Töötukassa	3	1	762	4 287 080
Sihtasutus KredEx	6	2	111	2 829 795
PRIA	21	5	97	55 454 237
SA KIK	11	2	89	490 622 906
Tallinna Ettevõtlusamet	6	3	81	775 324
Sihtasutus Archimedes	8	4	35	2 030 849
Sihtasutus INNOVE	2	1	13	2 322 839
Elering AS	4	1	10	51 432 024
Keskkonnaministeerium	3	1	7	1 837 749
SA Erametsakeskus	3	1	7	21 662
Maaelu Edendamise SA	4	2	6	29 997
Rahandusministeerium	6	2	5	13 308 016
Tehnilise Järelevalve Amet	3	1	5	204 748 317
MKM	5	2	4	81 660 437
Eesti Filmi SA	3	1	3	2 530 044
Siseministeerium	1	1	3	331 032
Kultuuriministeerium	2	1	2	121 342
Sihtasutus Eesti Teadusagentuur	1	1	2	7 669
Aktsiaselts Tallinna Lennujaam	2	1	1	20 486 550
Narva Linna A. ja Ö. Amet	1	1	1	49 540
Veeteede Amet	1	1	1	1 917 348

Source: Innovation Data (2018)

IV. Beneficiaries use of instruments

Use of policy instruments by firms in the CIS sample by instrument type (2002 - 2012)

Instrument type	2004	2006	2008	2010	2012
Collaboration programmes	0	0	2	6	4
Consulting	0	0	0	31	359
Direct subsidy	0	0	1	2	2
Financial guarantees	0	0	0	62	81
Innovation & R&D	11	33	25	130	222
Investments	60	114	107	196	147
Labour support	0	0	2	490	660
Marketing & export promotion	45	108	79	279	250
Mixed support	0	3	6	9	17
Training & skills	121	354	298	577	563

Source: Innovation Data (2018)

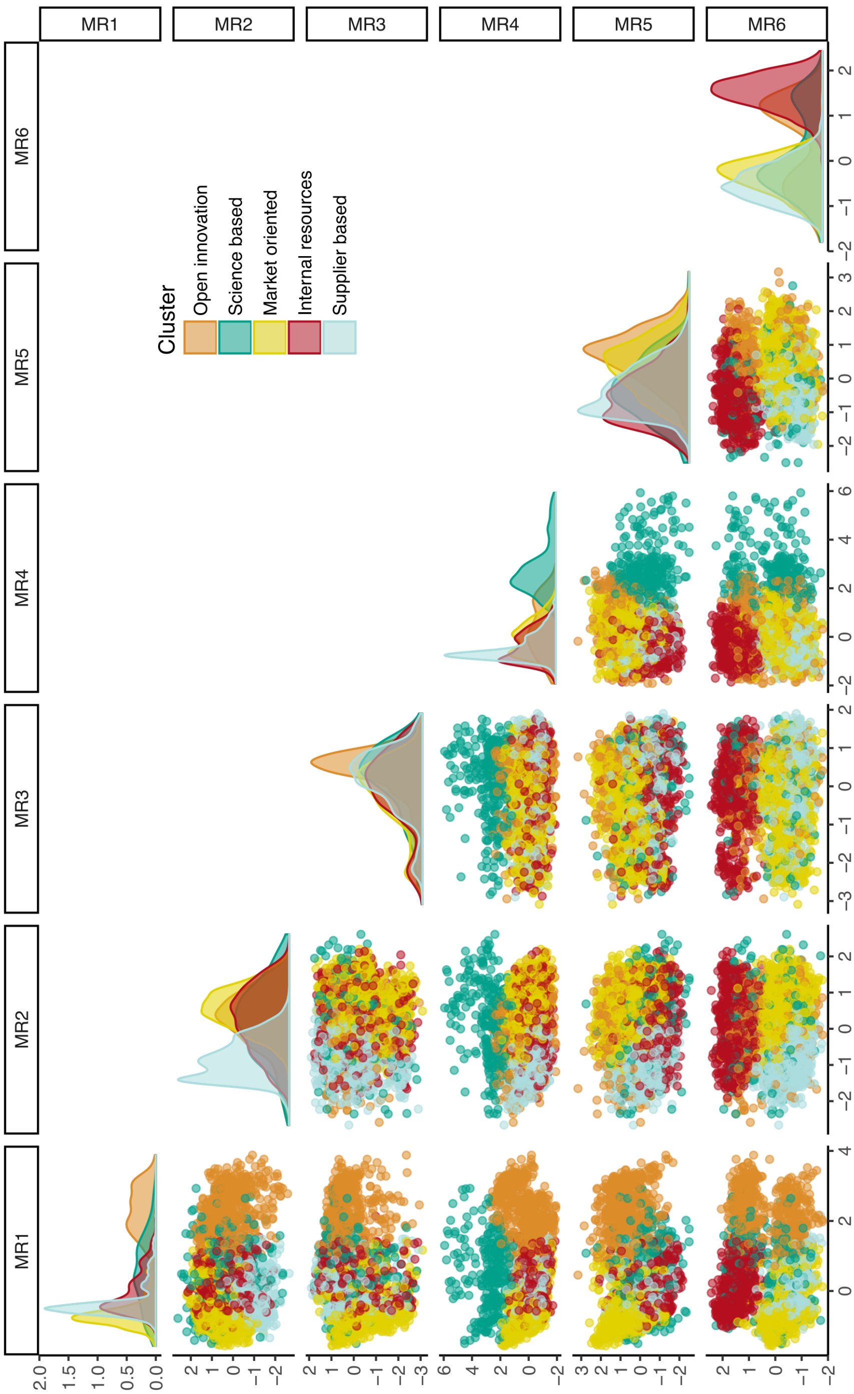
V. Total sum allocated to beneficiares by instrument type

Total sum allocated to firms in the CIS sample by instrument type (2002 - 2012)

Instrument type	2004	2006	2008	2010	2012
Collaboration prog.	0	0	29 977	312 531	235 994
Consulting	0	0	0	1 966 686	3 394 014
Direct subsidy	0	0	86	20 451 728	60 029 728
Financial guarantees	0	0	0	1 390 163	1 407 859
Innovation & R&D	1 129 413	3 893 111	2 408 887	9 951 306	16 260 537
Investments	18 952 552	25 374 304	187 599 811	492 584 472	194 771 112
Labour support	0	0	1 917	3 327 068	3 997 454
Marketing & export	1 850 867	5 230 984	5 200 358	15 304 216	14 606 888
Mixed support	0	27 627	57 665	142 855	489 931
Training & skills	387 018	3 077 391	2 855 159	4 034 417	4 312 222

Source: Innovation Data (2018)

VI. Factor loadings matrix plot with clusters

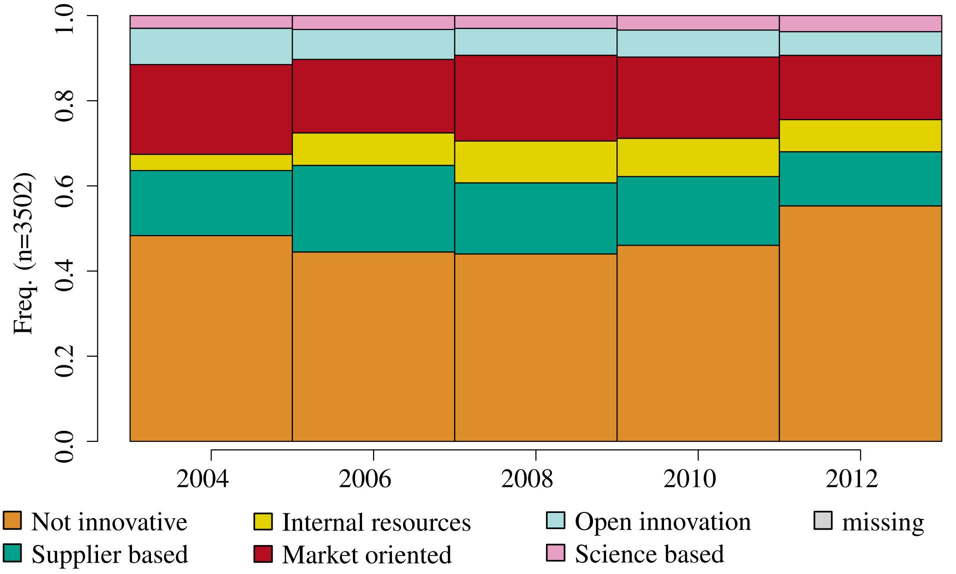


VII. Innovative activities by pattern of innovation

	Open innovation	Science based	Market oriented	Internal strategy	Supplier based
Mean importance of sources, 0-3					
sources: internal	2.29	2.25	1.94	2.60	1.27
sources: suppliers	2.18	1.77	1.48	1.58	1.79
sources: clients	2.05	1.57	1.83	1.30	0.93
sources: competitors	1.84	1.00	1.43	0.95	0.78
sources: consultants	1.26	1.05	0.63	0.64	0.42
sources: universities	0.82	1.66	0.33	0.23	0.14
sources: public research inst.	0.51	0.62	0.22	0.12	0.10
sources: conferences	1.70	1.62	1.40	0.97	1.02
sources: magazines	1.37	1.33	0.90	0.68	0.58
sources: trade associations	0.86	0.68	0.46	0.38	0.31
Funding for inputs, share of sample					
inputs: outsourced R&D	0.57	0.72	0.24	0.29	0.14
inputs: internal R&D	0.76	0.92	0.55	0.47	0.22
inputs: machinery	0.93	0.88	0.81	0.85	0.91
inputs: knowledge	0.72	0.64	0.44	0.49	0.25
inputs: training	0.75	0.63	0.55	0.64	0.41
inputs: marketing	0.56	0.59	0.60	0.42	0.05
Cooperation with partners, share of sample					
coop: within group	0.57	0.30	0.01	0.99	0.01
coop: suppliers	0.93	0.48	0.08	0.30	0.15
coop: clients	0.90	0.44	0.13	0.25	0.05
coop: competitors	0.89	0.10	0.04	0.04	0.03
coop: consultants	0.62	0.32	0.01	0.07	0.03
coop: universities	0.43	0.70	0.00	0.01	0.01
coop: public research inst.	0.25	0.14	0.01	0.01	0.00
Mean importance of goals, 0-3					
goal: portfolio widening	2.12	2.17	2.42	1.94	0.69
goal: new markets	2.18	2.13	2.20	1.83	1.11
goal: quality increase	2.44	2.26	2.06	2.08	1.84
goal: flexibility in production	2.20	1.86	1.79	1.86	1.53
goal: productivity increase	2.20	1.86	1.71	1.82	1.60
goal: lower labour cost	1.90	1.51	1.45	1.55	1.26
Use of appropriation methods, share of sample					
appr: industrial models	0.00	0.36	0.00	0.00	0.00
appr: patents	0.00	0.13	0.00	0.00	0.00
appr: industrial designs	0.00	0.36	0.00	0.00	0.00
appr: trademarks	0.51	1.01	0.45	0.25	0.22

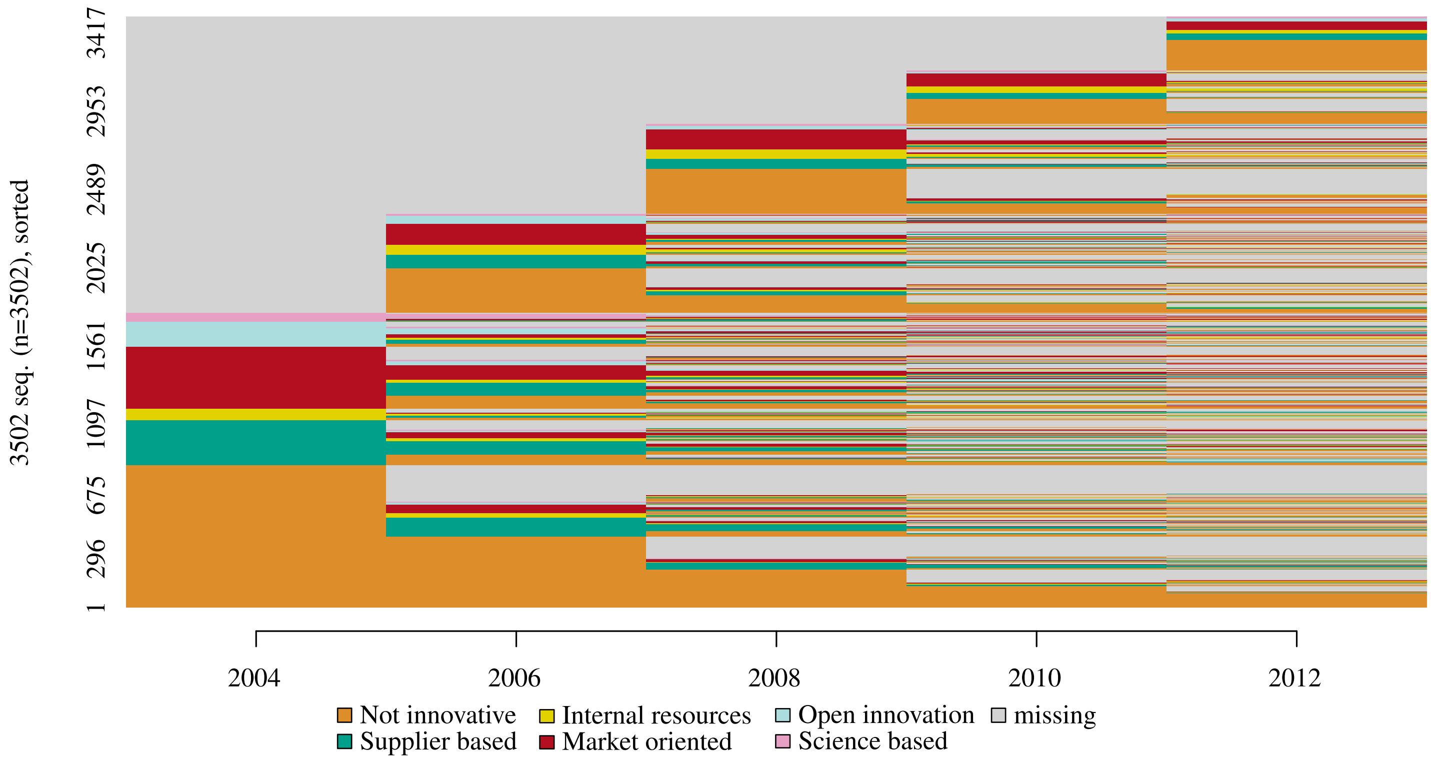
Source: Innovation Data (2018), n = 4811.

VIII. Pattern of innovation state distribution for full panel



Patterns of innovation state distribution plot over time. n = 9155 (obs); n = 3502 (firms).
Source: Innovation Data (2018)

IX. Pattern of innovation state sequences for full panel



Patterns of innovation state sequence plot over time. n = 9155 (obs); n = 3502 (firms). Source: Innovation Data (2018)

X. Full sample state transition matrix

State transition matrix, full sample, with time and missing states, in percentages.

From:	End Period	To: Not innov.	Supplier based	Internal strategy	Market oriented	Open innov.	Science based	Missing
Not innovative	2006	49.9	13.3	3.2	5.8	1.5	0.6	25.7
Supplier based	2006	22.9	30.7	6.7	12.7	3.8	1.9	21.4
Internal strategy	2006	20.9	17.9	16.4	11.9	4.5	0.0	28.4
Market oriented	2006	21.2	20.4	4.9	23.9	6.0	2.7	20.9
Open innovation	2006	11.4	15.4	8.1	14.1	24.8	5.4	20.8
Science based	2006	5.8	11.5	0.0	15.4	5.8	48.1	13.5
Missing	2006	14.9	4.6	3.5	7.1	2.7	0.6	66.7
Not innovative	2008	48.3	9.4	2.3	5.7	1.3	0.5	32.6
Supplier based	2008	24.0	25.8	6.4	17.1	4.4	2.3	20.0
Internal strategy	2008	15.7	15.7	29.3	14.3	6.1	1.4	17.7
Market oriented	2008	12.4	13.0	8.4	27.4	8.4	1.8	28.6
Open innovation	2008	8.2	11.1	11.9	20.0	23.0	5.2	20.7
Science based	2008	6.4	4.8	3.2	28.6	3.2	31.8	22.2
Missing	2008	19.4	4.6	4.1	8.6	1.9	0.8	60.6
Not innovative	2010	44.0	5.6	1.9	4.3	1.2	0.2	42.8
Supplier based	2010	26.0	27.8	3.3	11.2	3.9	1.2	26.6
Internal strategy	2010	17.6	7.5	29.2	10.6	7.0	1.0	27.1
Market oriented	2010	16.4	15.0	4.4	26.2	3.4	3.9	30.6
Open innovation	2010	7.0	12.5	8.6	18.0	27.3	5.5	21.1
Science based	2010	11.5	6.6	3.3	18.0	11.5	31.2	18.0
Missing	2010	13.6	2.7	2.6	6.3	1.1	0.6	73.0
Not innovative	2012	56.6	5.8	2.1	3.6	1.1	0.3	30.5
Supplier based	2012	35.7	22.5	4.3	8.9	1.4	1.1	26.1
Internal strategy	2012	24.4	7.1	23.7	12.8	4.5	3.2	24.4
Market oriented	2012	26.6	10.0	5.7	24.2	4.2	3.3	26.0
Open innovation	2012	10.9	5.5	16.4	19.1	26.4	8.2	13.6
Science based	2012	1.7	5.1	3.4	17.0	17.0	30.5	25.4
Missing	2012	14.8	3.2	1.4	4.2	1.3	1.0	74.0

Source: Innovation Data (2018), n = 9155.

XI. Public support and patterns of innovation. Base model estimates.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
Consulting	0.103	0.167	0.171	0.214	−0.024
	(0.217)	(0.151)	(0.200)	(0.233)	(0.177)
Financial	−0.371	0.223	0.130	−0.170	0.194
	(0.421)	(0.257)	(0.377)	(0.448)	(0.262)
Innovation and R&D	−0.374	0.398**	0.821***	1.716***	−0.240
	(0.263)	(0.159)	(0.195)	(0.214)	(0.201)
Investments	0.213	0.814***	0.645***	1.093***	1.182***
	(0.207)	(0.143)	(0.179)	(0.228)	(0.135)
Labour	−0.397***	−0.255***	−0.760***	−0.598***	−0.298***
	(0.146)	(0.097)	(0.161)	(0.206)	(0.103)
Marketing	0.460**	1.044***	0.922***	1.161***	0.468***
	(0.182)	(0.132)	(0.180)	(0.207)	(0.146)
Training	1.081***	0.504***	1.093***	1.100***	0.555***
	(0.112)	(0.086)	(0.119)	(0.151)	(0.090)
Mixed	−0.548	1.111***	0.173	0.061	0.717
	(1.093)	(0.448)	(0.830)	(0.971)	(0.558)
Other	−8.506	−0.444	2.213***	2.683***	0.954
	(0.524)	(1.084)	(0.655)	(0.676)	(0.441)
Constant	−2.031***	−1.161***	−2.292***	−3.288***	−1.233***
	(0.060)	(0.042)	(0.068)	(0.109)	(0.041)
Observations	9155				
Akaike Inf. Crit.	25,824.620				
Log likelihood	-12,862.31				
Note:					*p<0.1; **p<0.05; ***p<0.01

XII. Public support and patterns of innovation. Base model with time controls estimates.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
Consulting	0.317	0.656***	0.676***	0.710***	0.369**
	(0.231)	(0.167)	(0.232)	(0.275)	(0.188)
Financial	−0.301	0.430*	0.386	0.106	0.377
	(0.415)	(0.237)	(0.342)	(0.446)	(0.256)
Innovation and R&D	−0.279	0.668***	1.129***	2.056***	−0.021
	(0.255)	(0.152)	(0.184)	(0.196)	(0.190)
Investments	0.220	0.855***	0.696***	1.146***	1.213***
	(0.191)	(0.124)	(0.171)	(0.194)	(0.120)
Labour	−0.263*	0.239**	−0.217	−0.029	0.109
	(0.146)	(0.105)	(0.168)	(0.211)	(0.111)
Marketing	0.444***	1.071***	0.965***	1.216***	0.478***
	(0.168)	(0.114)	(0.153)	(0.183)	(0.132)
Training	1.034***	0.591***	1.232***	1.218***	0.593***
	(0.101)	(0.081)	(0.108)	(0.146)	(0.083)
Mixed	−0.586	1.177***	0.264	0.138	0.759
	(1.056)	(0.436)	(0.800)	(1.089)	(0.504)
Other	−9.142	−0.531	2.188***	2.676***	0.877
	(121.470)	(1.170)	(0.774)	(0.804)	(0.831)
CIS2006	0.655***	−0.225**	−0.324**	−0.128	0.280***
	(0.156)	(0.091)	(0.131)	(0.199)	(0.094)
CIS2008	0.955***	−0.021	−0.349***	−0.095	0.117
	(0.150)	(0.087)	(0.132)	(0.198)	(0.096)
CIS2010	0.672***	−0.543***	−0.874***	−0.855***	−0.224**
	(0.162)	(0.101)	(0.152)	(0.225)	(0.108)
CIS2012	0.302*	−1.166***	−1.420***	−1.347***	−0.697***
	(0.173)	(0.116)	(0.178)	(0.255)	(0.120)
Constant	−2.616***	−0.919***	−1.886***	−2.996***	−1.236***
	(0.128)	(0.063)	(0.091)	(0.145)	(0.071)
Observations	9155				
Akaike Inf. Crit.	25,566.690				
Log likelihood	-12,713.35				
Note:					*p<0.1; **p<0.05; ***p<0.01

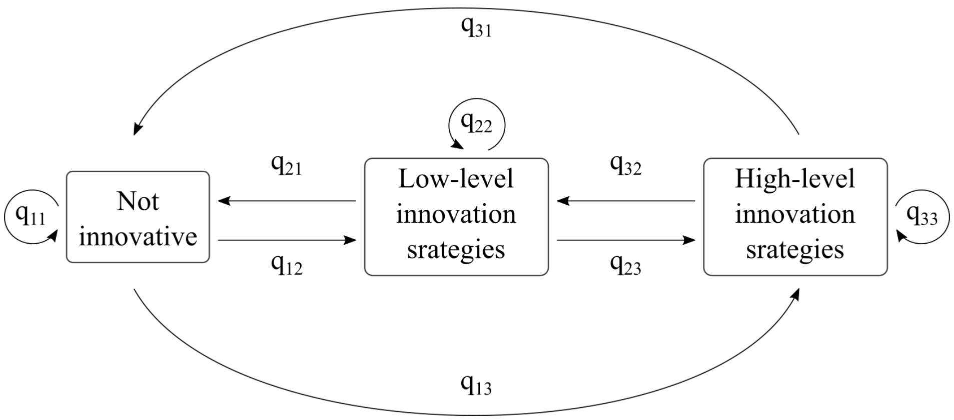
XIII. Public support and patterns of innovation. Base model with time and firm specific controls estimates.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
Consulting	0.054	0.564***	0.371	0.383	0.223
	(0.246)	(0.170)	(0.236)	(0.280)	(0.189)
Financial	−0.316	0.334	0.411	0.127	0.350
	(0.429)	(0.237)	(0.345)	(0.449)	(0.257)
Innovation and R&D	0.004	0.724***	1.254***	2.168***	0.006
	(0.263)	(0.154)	(0.188)	(0.201)	(0.191)
Investments	0.326	0.909***	0.637***	1.042***	1.150***
	(0.203)	(0.128)	(0.176)	(0.200)	(0.123)
Labour	−0.400**	0.129	−0.403**	−0.270	−0.005
	(0.155)	(0.107)	(0.172)	(0.214)	(0.113)
Marketing	0.280	0.902***	0.799***	1.002***	0.377***
	(0.177)	(0.116)	(0.157)	(0.186)	(0.134)
Training	0.686***	0.440***	0.899***	0.822***	0.440***
	(0.111)	(0.083)	(0.112)	(0.151)	(0.085)
Mixed	−0.618	0.936**	0.618	0.659	1.113**
	(1.065)	(0.441)	(0.806)	(1.089)	(0.510)
Other	−5.006***	−0.386	2.285***	2.660***	0.959
	(0.003)	(1.194)	(0.832)	(0.865)	(0.847)
CIS2006	0.838***	−0.149	−0.215	0.002	0.295***
	(0.162)	(0.093)	(0.135)	(0.202)	(0.095)
CIS2008	1.377***	0.130	−0.147	0.101	0.120
	(0.157)	(0.090)	(0.137)	(0.204)	(0.098)
CIS2010	1.284***	−0.277***	−0.500***	−0.433*	−0.165
	(0.172)	(0.105)	(0.161)	(0.236)	(0.113)
CIS2012	1.054***	−0.857***	−0.952***	−0.819***	−0.644***
	(0.184)	(0.121)	(0.187)	(0.268)	(0.127)
firm_age	−0.110***	−0.046***	−0.032***	−0.030**	0.013**
	(0.008)	(0.006)	(0.010)	(0.013)	(0.007)
firm_exporter	0.365***	0.575***	0.170	0.456**	0.066

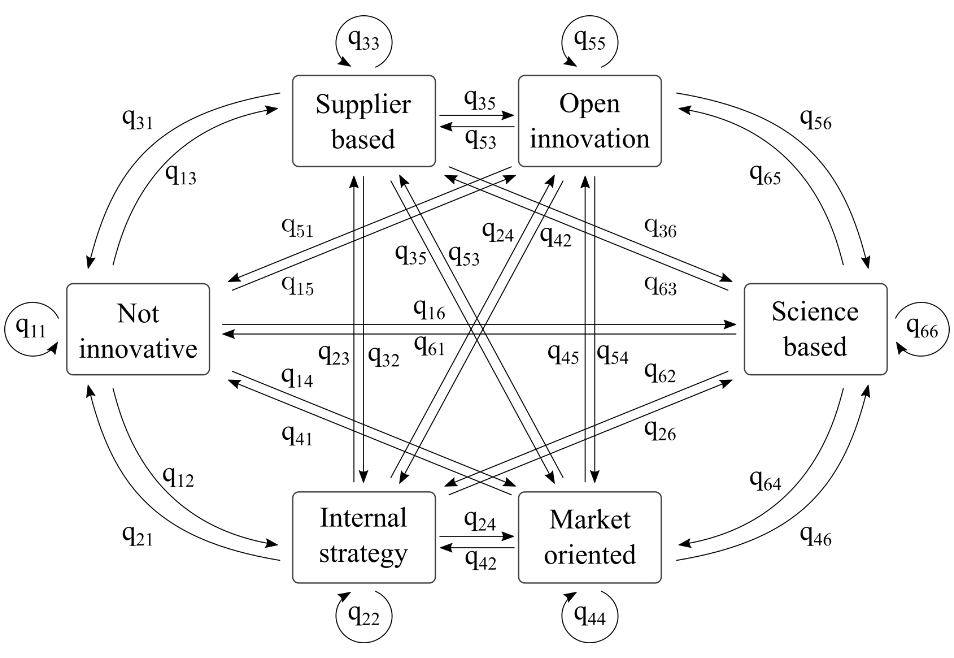
Continued.

	Multinomial logit. Ref. category: not innovative				
	Internal strategy	Market oriented	Open innovation	Science based	Supplier based
	(1)	(2)	(3)	(4)	(5)
	(0.124)	(0.077)	(0.121)	(0.190)	(0.073)
firm_log_worker	0.688***	0.290***	0.673***	0.793***	0.334***
	(0.044)	(0.033)	(0.045)	(0.060)	(0.034)
firm_foreign_owned	1.378***	0.091	0.560***	0.171	−0.049
	(0.093)	(0.071)	(0.098)	(0.141)	(0.077)
Constant	−5.138***	−1.976***	−4.422***	−6.152***	−2.581***
	(0.233)	(0.141)	(0.210)	(0.316)	(0.147)
Observations	9155				
Akaike Inf. Crit.	24,391.190				
Log likelihood	-12,105.59				
Note:					*p<0.1; **p<0.05; ***p<0.01

XIV. Three-state and six-state Markov models for innovation strategies.



Three-state Markov model for innovation strategies.



Six-state Markov model for innovation strategies.

XV. Frequency tables for use of instruments and state transitions for balanced dataset in the three- and six-state Markov models

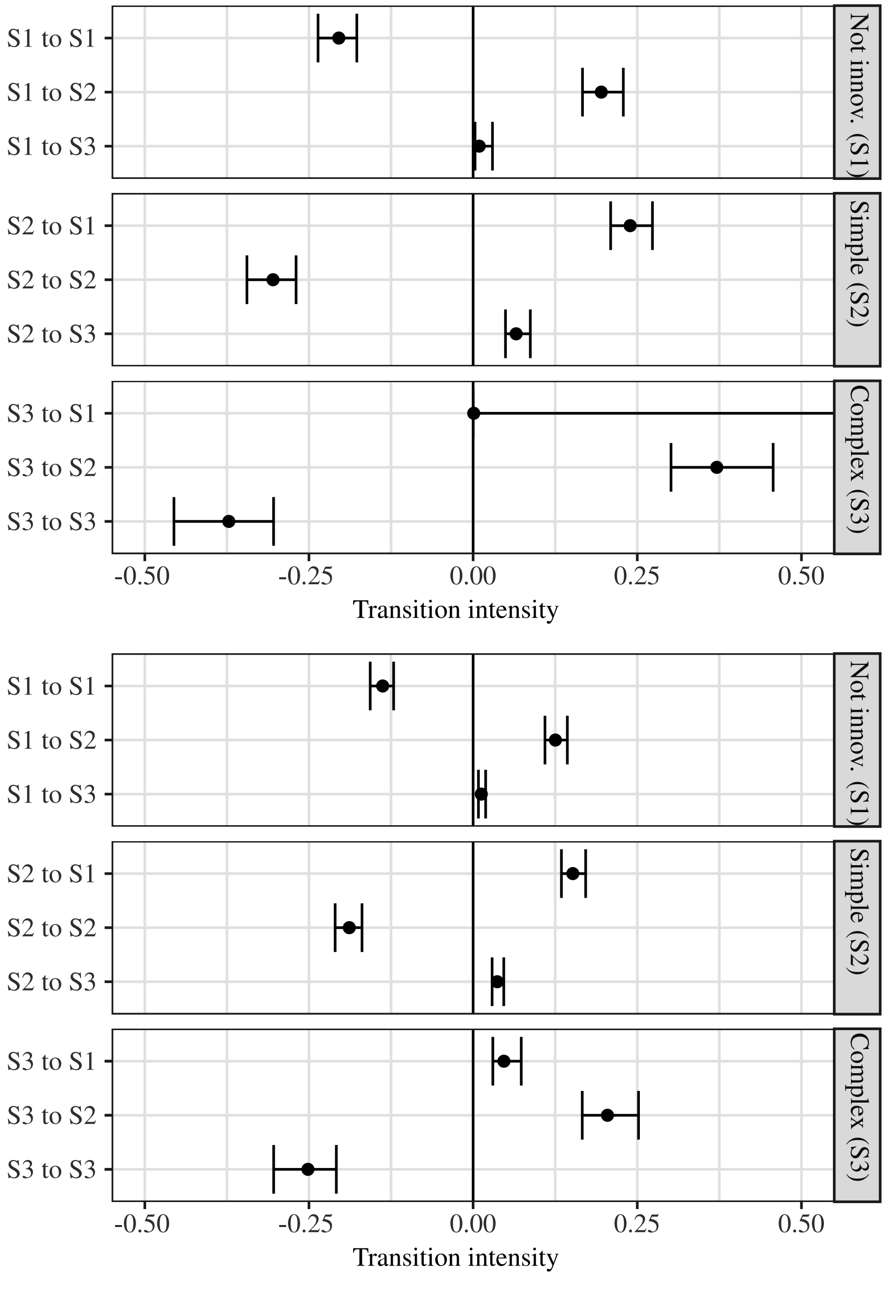
Frequency table of state transitions in three-state Markov model with balanced dataset. n = 3270 obs.

From	To Not innovative (1)	Simple innovation strategies (2)	Complex innovation strategies (3)
Not innovative (1)	745	260	25
Simple innovation strategies (2)	345	789	116
Complex innovation strategies (3)	27	146	163

Use of instruments in the three- and six-state Markov models with balanced dataset. n = 3276 obs.

	2004	2006	2008	2010	2012
Observations	654	654	654	654	654
Innovation & R&D	7	18	13	55	92
Investments	32	55	57	92	73
Marketing & export promotion	23	43	31	117	106
Training & skills development	60	137	101	255	262

XVI. Three-state Markov model transition intensities, balanced data model plots



Upper: intermittently observed model; lower: exactly observed model.

XVII. Transition intensity matrices for three-state Markov models

Transition intensity matrix. Three-state Markov model with full dataset and intermittently observed transitions. Intensities with 95% confidence intervals.

From:	To: Not innovative	Simple	Complex
Not innovative	-0.184 (-0.202; -0.167)	0.179 (0.160; 0.199)	0.005 (0.001; 0.019)
Simple	0.266 (0.244; 0.290)	-0.340 (-0.37; -0.313)	0.075 (0.061; 0.092)
Complex	0.000 (0.00; 1.27e+117)	0.464 (0.401; 0.536)	-0.464 (-0.536; -0.401)

Transition intensity matrix. Three-state Markov model with full dataset and exactly observed transitions. Intensities with 95% confidence intervals.

From:	To: Not innovative	Simple	Complex
Not innovative	-0.118 (-0.129; -0.109)	0.108 (0.098; 0.118)	0.011 (0.008; 0.014)
Simple	0.160 (0.148; 0.173)	-0.194 (-0.208; -0.181)	0.034 (0.028; 0.040)
Complex	0.062 (0.048; 0.082)	0.211 (0.183; 0.244)	-0.274 (-0.311; -0.241)

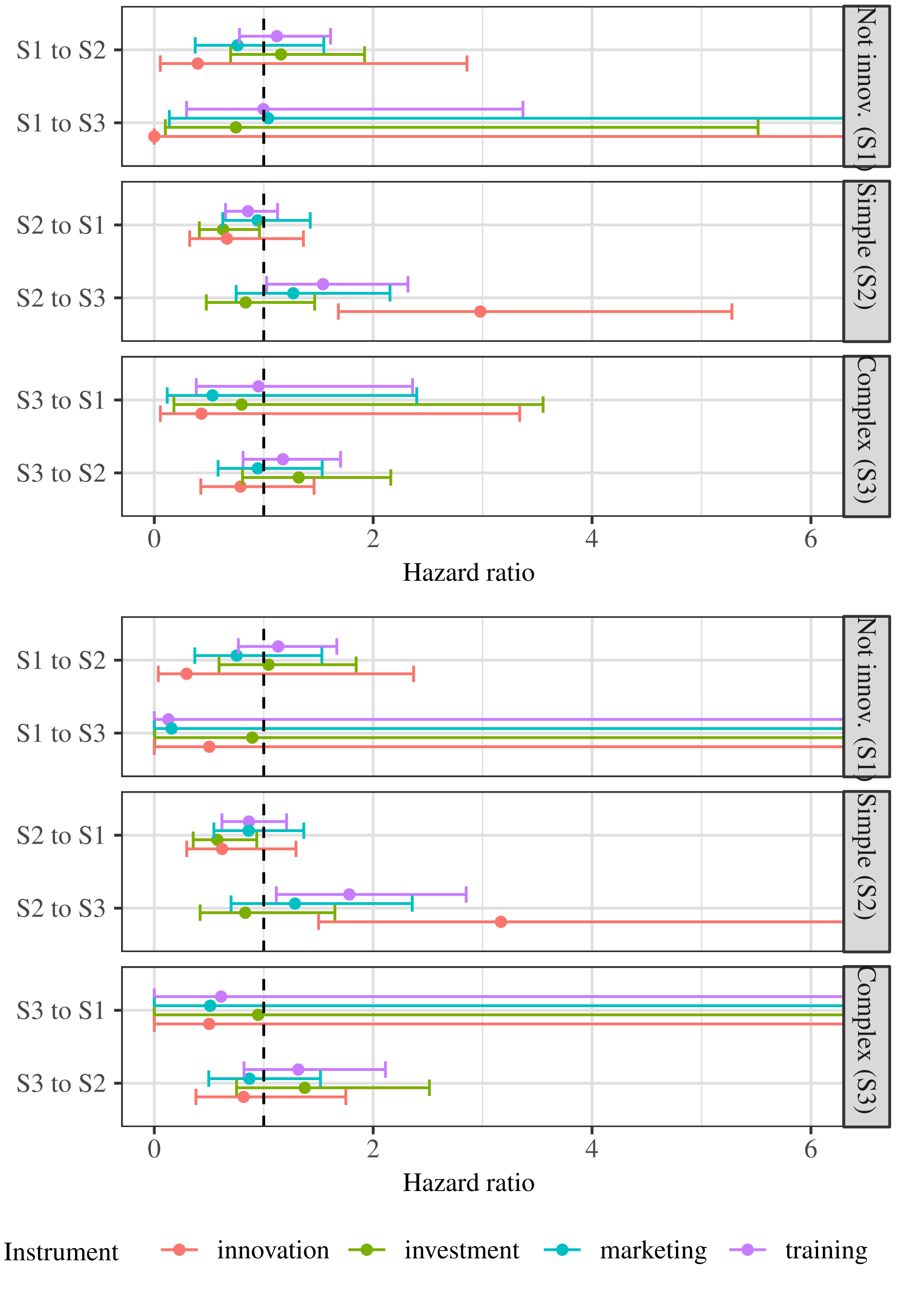
Transition intensity matrix. Three-state Markov model with balanced dataset and intermittently observed transitions. Intensities with 95% confidence intervals.

From:	To: Not innovative	Simple	Complex
Not innovative	-0.205 (-0.236; -0.177)	0.195 (0.167; 0.229)	0.009 (0.003; 0.03)
Simple	0.239 (0.209; 0.273)	-0.305 (-0.344; -0.27)	0.066 (0.049; 0.087)
Complex	0.001 (0; 5335.987)	0.371 (0.301; 0.457)	-0.372 (-0.456; -0.304)

Transition intensity matrix. Three-state Markov model with balanced dataset and exactly observed transitions. Intensities with 95% confidence intervals.

From:	To: Not innovative	Simple	Complex
Not innovative	-0.138 (-0.157; -0.121)	0.125 (0.109; 0.143)	0.012 (0.008; 0.019)
Simple	0.152 (0.134; 0.171)	-0.189 (-0.210; -0.169)	0.037 (0.029; 0.047)
Complex	0.047 (0.030; 0.073)	0.205 (0.166; 0.252)	-0.252 (-0.304; -0.208)

XVIII. Three-state Markov model hazard ratios, balanced data model plots



Upper: intermittently observed model; lower: exactly observed model.

XIX. Hazard ratios for innovation policy instruments in three-state Markov models

Hazard ratios with 95% confidence intervals. three-state Markov model with full dataset and intermittently observed transitions.

Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0.502 (0.169; 1.495)	1.585 (1.067; 2.354)	0.651 (0.323; 1.311)	1.156 (0.866; 1.542)
State 1 to State 3	2.821 (0.587; 13.552)	0.000 (0; Inf)	8.876 (2.033; 38.757)	2.485 (0.644; 9.593)
State 2 to State 1	0.844 (0.495; 1.439)	0.581 (0.406; 0.832)	0.73 (0.530; 1.007)	0.772 (0.612; 0.973)
State 2 to State 3	2.426 (1.383; 4.257)	0.987 (0.626; 1.555)	1.165 (0.718; 1.89)	1.799 (1.279; 2.53)
State 3 to State 1	0.000 (0; Inf)	1.056 (0.015; 75.86)	0.000 (0; Inf)	21247.633 (0; 1.620e+127)
State 3 to State 2	0.609 (0.345; 1.074)	1.021 (0.668; 1.56)	1.091 (0.734; 1.62)	1.045 (0.762; 1.434)

Hazard ratios with 95% confidence intervals. three-state Markov model with full dataset and exactly observed transitions.

Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0.686 (0.281; 1.672)	1.520 (1.045; 2.211)	0.888 (0.541; 1.457)	1.172 (0.911; 1.508)
State 1 to State 3	1.514 (0.354; 6.479)	1.201 (0.376; 3.841)	2.757 (1.183; 6.423)	1.725 (0.916; 3.246)
State 2 to State 1	0.819 (0.486; 1.378)	0.583 (0.423; 0.804)	0.817 (0.609; 1.096)	0.781 (0.644; 0.949)
State 2 to State 3	2.796 (1.813; 4.311)	1.021 (0.693; 1.504)	1.295 (0.899; 1.865)	1.832 (1.384; 2.423)
State 3 to State 1	0.386 (0.093; 1.610)	0.768 (0.302; 1.957)	0.298 (0.091; 0.978)	1.066 (0.623; 1.826)
State 3 to State 2	0.627 (0.382; 1.030)	1.097 (0.759; 1.585)	1.228 (0.876; 1.720)	1.042 (0.800; 1.358)

Hazard ratios with 95% confidence intervals. three-state Markov model with balanced dataset and intermittently observed transitions.

Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0.295 (0.037; 2.37)	1.044 (0.591; 1.845)	0.753 (0.37; 1.531)	1.132 (0.769; 1.668)
State 1 to State 3	0.503 (0; 237.1e+4)	0.895 (0.005; 171.98)	0.158 (0; 929.903)	0.129 (0; 640.028)
State 2 to State 1	0.619 (0.296; 1.295)	0.577 (0.355; 0.936)	0.862 (0.545; 1.366)	0.864 (0.618; 1.209)
State 2 to State 3	3.167 (1.501; 6.682)	0.831 (0.419; 1.65)	1.285 (0.701; 2.357)	1.782 (1.115; 2.85)
State 3 to State 1	0.502 (0; 2.224e+27)	0.949 (0; 1.445e+75)	0.511 (0; 2.364e+61)	0.61 (0; 9.295e+73)
State 3 to State 2	0.816 (0.381; 1.75)	1.375 (0.752; 2.514)	0.869 (0.498; 1.518)	1.316 (0.82; 2.112)

Hazard ratios with 95% confidence intervals. three-state Markov model with balanced dataset and exactly observed transitions.

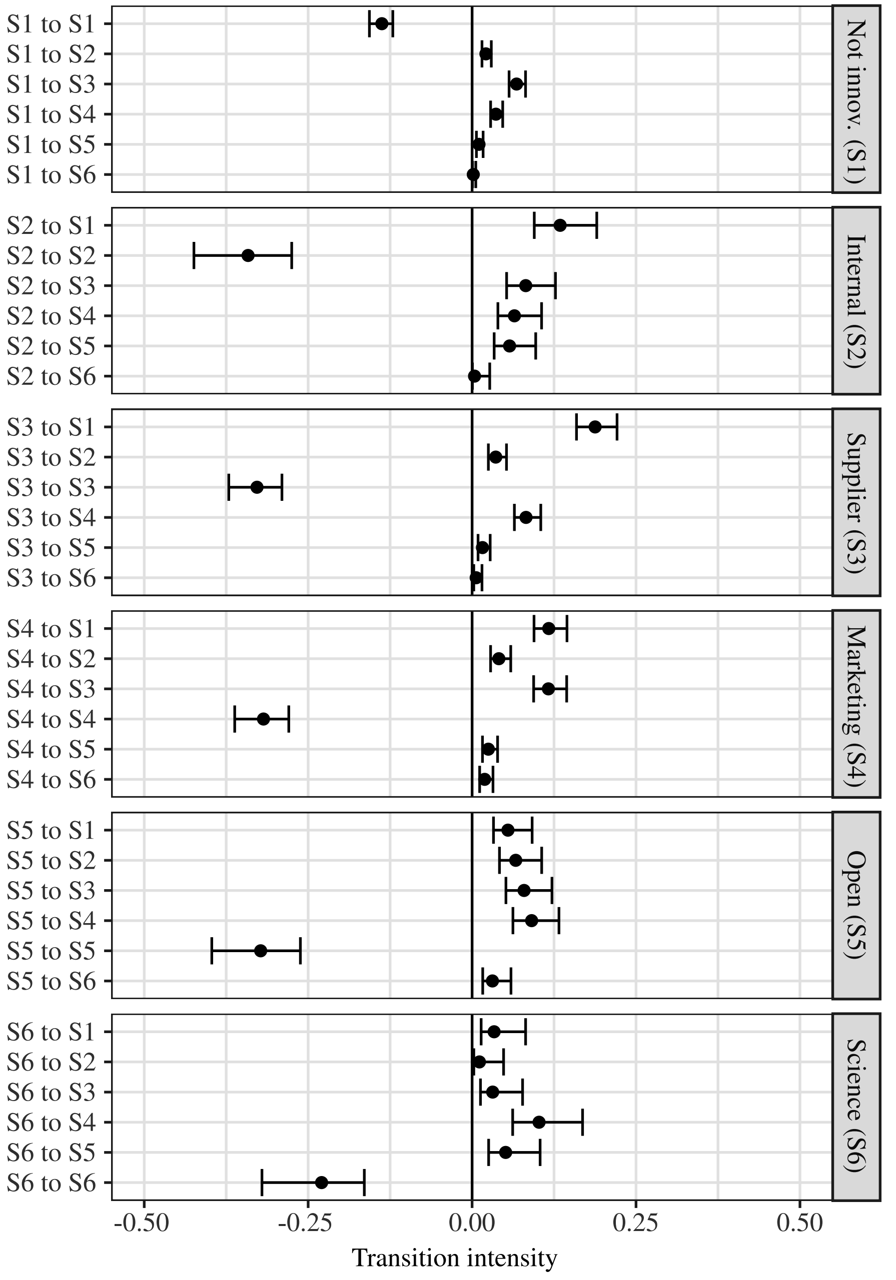
Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0.397 (0.055; 2.857)	1.158 (0.697; 1.921)	0.761 (0.374; 1.549)	1.120 (0.778; 1.611)
State 1 to State 3	0.000 (0; 2.113e+180)	0.745 (0.101; 5.517)	1.040 (0.138; 7.842)	0.997 (0.295; 3.369)
State 2 to State 1	0.664 (0.323; 1.363)	0.629 (0.411; 0.961)	0.944 (0.625; 1.425)	0.856 (0.651; 1.126)
State 2 to State 3	2.979 (1.682; 5.278)	0.835 (0.475; 1.465)	1.269 (0.748; 2.154)	1.542 (1.026; 2.318)
State 3 to State 1	0.431 (0.056; 3.339)	0.798 (0.179; 3.553)	0.532 (0.118; 2.398)	0.952 (0.384; 2.36)
State 3 to State 2	0.788 (0.425; 1.460)	1.320 (0.806; 2.161)	0.946 (0.583; 1.534)	1.175 (0.811; 1.702)

XX. Frequency table for state transitions with balanced dataset in the six-state Markov model

Frequency table of state transitions in a six-state Markov model with balanced dataset.

From	To: Not innov.	Internal	Supplier	Market	Open	Science
Not innovative	745	44	142	74	21	4
Internal strategy	48	59	28	29	20	4
Supplier based	178	38	198	95	19	10
Market oriented	119	38	112	192	39	24
Open innovation	19	30	27	49	77	16
Science based	8	3	10	27	14	56

XXI. Six-state Markov model transition intensities for the balanced dataset with exact transitions



XXII. Transition intensity matrices for six-state Markov models

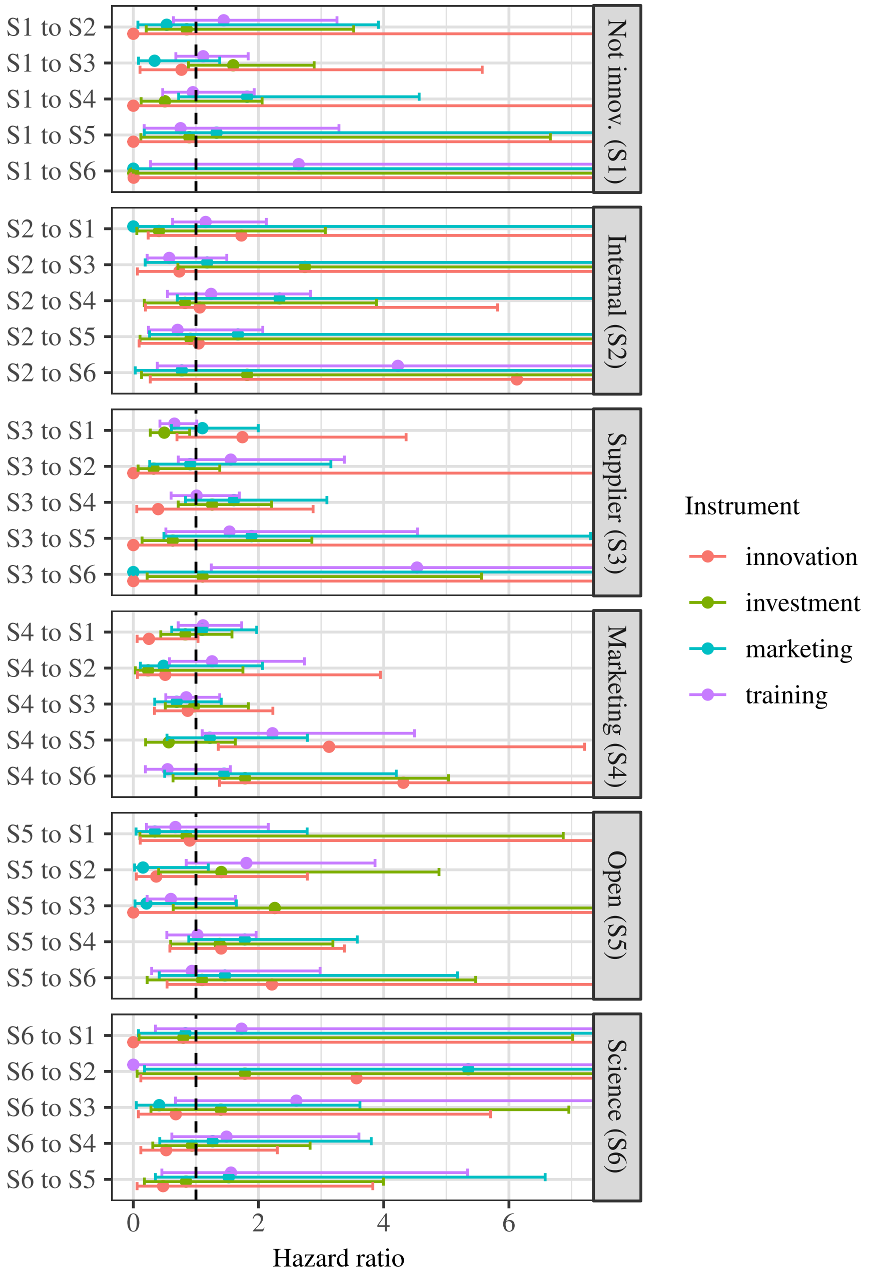
Transition intensity matrix. Six-state Markov model with full dataset and exactly observed transitions. Intensities with 95% confidence intervals.

To: From:	Not innov. (1)	Internal (2)	Supplier (3)	Marketing (4)	Open (5)	Science (6)
1	-0.118 (-0.129; -0.109)	0.016 (0.013; 0.02)	0.057 (0.05; 0.064)	0.035 (0.03; 0.041)	0.008 (0.006; 0.011)	0.003 (0.001; 0.005)
2	0.14 (0.114; 0.172)	-0.321 (-0.367; -0.281)	0.064 (0.048; 0.086)	0.082 (0.063; 0.106)	0.032 (0.021; 0.049)	0.003 (0.001; 0.01)
3	0.187 (0.167; 0.21)	0.03 (0.023; 0.04)	-0.317 (-0.346; -0.29)	0.071 (0.06; 0.086)	0.02 (0.015; 0.029)	0.008 (0.004; 0.013)
4	0.143 (0.126; 0.162)	0.035 (0.027; 0.045)	0.096 (0.082; 0.112)	-0.313 (-0.34; -0.287)	0.026 (0.02; 0.035)	0.012 (0.008; 0.019)
5	0.067 (0.049; 0.092)	0.059 (0.042; 0.081)	0.079 (0.059; 0.105)	0.099 (0.077; 0.126)	-0.326 (-0.375; -0.284)	0.023 (0.014; 0.038)
6	0.051 (0.029; 0.089)	0.013 (0.005; 0.039)	0.038 (0.02; 0.072)	0.096 (0.064; 0.143)	0.048 (0.027; 0.084)	-0.246 (-0.316; -0.192)

Transition intensity matrix. Six-state Markov model with balanced dataset and exactly observed transitions. Intensities with 95% confidence intervals.

To: From:	Not innov. (1)	Internal (2)	Supplier (3)	Marketing (4)	Open (5)	Science (6)
1	-0.138 (-0.157; -0.121)	0.021 (0.015; 0.029)	0.068 (0.056; 0.082)	0.036 (0.028; 0.047)	0.011 (0.007; 0.017)	0.002 (0.001; 0.006)
2	0.134 (0.095; 0.19)	-0.342 (-0.424; -0.275)	0.082 (0.053; 0.127)	0.065 (0.039; 0.106)	0.057 (0.034; 0.097)	0.004 (0.001; 0.027)
3	0.188 (0.159; 0.221)	0.036 (0.025; 0.052)	-0.328 (-0.371; -0.29)	0.082 (0.065; 0.105)	0.016 (0.009; 0.028)	0.006 (0.003; 0.015)
4	0.117 (0.094; 0.145)	0.041 (0.028; 0.059)	0.116 (0.094; 0.144)	-0.318 (-0.362; -0.28)	0.025 (0.016; 0.039)	0.019 (0.012; 0.032)
5	0.055 (0.033; 0.092)	0.067 (0.042; 0.106)	0.079 (0.052; 0.122)	0.091 (0.062; 0.132)	-0.322 (-0.397; -0.262)	0.031 (0.016; 0.059)
6	0.034 (0.014; 0.082)	0.011 (0.003; 0.048)	0.031 (0.013; 0.077)	0.102 (0.062; 0.168)	0.051 (0.025; 0.104)	-0.229 (-0.32; -0.164)

XXIII. Hazard ratios for innovation policy instruments in the six-state Markov model with balanced dataset and exact transitions



XXIV. Hazard ratios for innovation policy instruments in six-state Markov models

Hazard ratios with 95% confidence intervals. Six-state Markov model with full dataset and exactly observed transitions.

Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0.001 (0; 5.152e+22)	1.061 (0.335; 3.362)	0.704 (0.169; 2.924)	1.39 (0.747; 2.585)
State 1 to State 3	0.263 (0.037; 1.889)	2.424 (1.583; 3.712)	0.617 (0.271; 1.406)	1.061 (0.738; 1.527)
State 1 to State 4	1.656 (0.595; 4.605)	0.445 (0.142; 1.393)	1.36 (0.674; 2.745)	1.269 (0.83; 1.941)
State 1 to State 5	0.001 (0; 1.790e+22)	1.698 (0.525; 5.49)	2.072 (0.704; 6.098)	2.067 (1.021; 4.183)
State 1 to State 6	7.053 (1.288; 38.621)	0.002 (0; 6.087e+23)	4.619 (1.061; 20.1)	1.034 (0.264; 4.051)
State 2 to State 1	1.569 (0.486; 5.064)	0.577 (0.18; 1.847)	0.428 (0.131; 1.404)	0.76 (0.484; 1.194)
State 2 to State 3	1.166 (0.261; 5.211)	2.209 (0.959; 5.088)	1.044 (0.38; 2.868)	0.946 (0.532; 1.679)
State 2 to State 4	0.875 (0.201; 3.815)	1.361 (0.527; 3.519)	2.182 (0.967; 4.924)	0.595 (0.329; 1.078)
State 2 to State 5	1.243 (0.16; 9.67)	0.939 (0.216; 4.084)	0.712 (0.158; 3.219)	1.578 (0.774; 3.217)
State 2 to State 6	5.781 (1.028; 32.524)	0.537 (0.056; 5.115)	2.734 (0.579; 12.918)	6.873 (1.357; 34.817)
State 3 to State 1	1.515 (0.745; 3.084)	0.522 (0.332; 0.819)	1.075 (0.711; 1.626)	0.714 (0.53; 0.963)
State 3 to State 2	0.654 (0.089; 4.794)	0.408 (0.145; 1.143)	0.77 (0.3; 1.976)	1.901 (1.107; 3.266)
State 3 to State 4	0.766 (0.243; 2.413)	1.377 (0.902; 2.102)	1.549 (0.973; 2.466)	1.189 (0.825; 1.714)
State 3 to State 5	0.001 (0; 7.335e+22)	0.824 (0.313; 2.171)	1.206 (0.45; 3.235)	1.437 (0.719; 2.875)
State 3 to State 6	1.791 (0.235; 13.678)	0.863 (0.242; 3.078)	1.24 (0.342; 4.496)	2.378 (0.948; 5.967)
State 4 to State 1	0.383 (0.141; 1.044)	0.613 (0.372; 1.011)	0.724 (0.463; 1.134)	0.908 (0.666; 1.238)
State 4 to State 2	0.243 (0.033; 1.784)	0.19 (0.046; 0.785)	0.968 (0.473; 1.981)	1.793 (1.095; 2.936)
State 4 to State 3	0.767 (0.333; 1.765)	1.298 (0.836; 2.015)	0.808 (0.494; 1.319)	0.791 (0.546; 1.147)
State 4 to State 5	2.746 (1.428; 5.279)	1.187 (0.642; 2.196)	1.099 (0.609; 1.983)	1.91 (1.179; 3.094)
State 4 to State 6	3.929 (1.778; 8.685)	1.327 (0.597; 2.946)	1.567 (0.757; 3.244)	1.71 (0.879; 3.325)
State 5 to State 1	0.505 (0.068; 3.741)	0.641 (0.151; 2.722)	0.162 (0.022; 1.198)	1.023 (0.546; 1.914)
State 5 to State 2	0.286 (0.038; 2.139)	1.116 (0.425; 2.931)	0.507 (0.175; 1.467)	1.602 (0.919; 2.792)

Continued.

Continuation of table.

Transition	Innovation	Investment	Marketing	Training
State 5 to State 3	0.382 (0.051; 2.865)	1.788 (0.731; 4.374)	0.373 (0.111; 1.252)	0.753 (0.408; 1.389)
State 5 to State 4	1.275 (0.602; 2.701)	1.276 (0.656; 2.482)	2.122 (1.244; 3.62)	0.731 (0.451; 1.184)
State 5 to State 6	1.466 (0.463; 4.64)	0.993 (0.319; 3.091)	1.407 (0.538; 3.678)	2.065 (0.958; 4.451)
State 6 to State 1	0.344 (0.044; 2.695)	0.977 (0.271; 3.523)	0.541 (0.112; 2.614)	1.131 (0.388; 3.29)
State 6 to State 2	1.909 (0.198; 18.421)	3.594 (0.587; 21.981)	0.953 (0.087; 10.476)	0.251 (0.026; 2.443)
State 6 to State 3	0.983 (0.266; 3.629)	0.593 (0.131; 2.685)	0.698 (0.182; 2.683)	1.718 (0.603; 4.901)
State 6 to State 4	0.28 (0.085; 0.924)	0.873 (0.414; 1.84)	1.828 (0.909; 3.678)	1.493 (0.778; 2.864)
State 6 to State 5	1.042 (0.334; 3.252)	0.712 (0.204; 2.481)	1.041 (0.344; 3.151)	1.406 (0.545; 3.623)

Hazard ratios with 95% confidence intervals. Six-state Markov model with balanced dataset and exactly observed transitions.

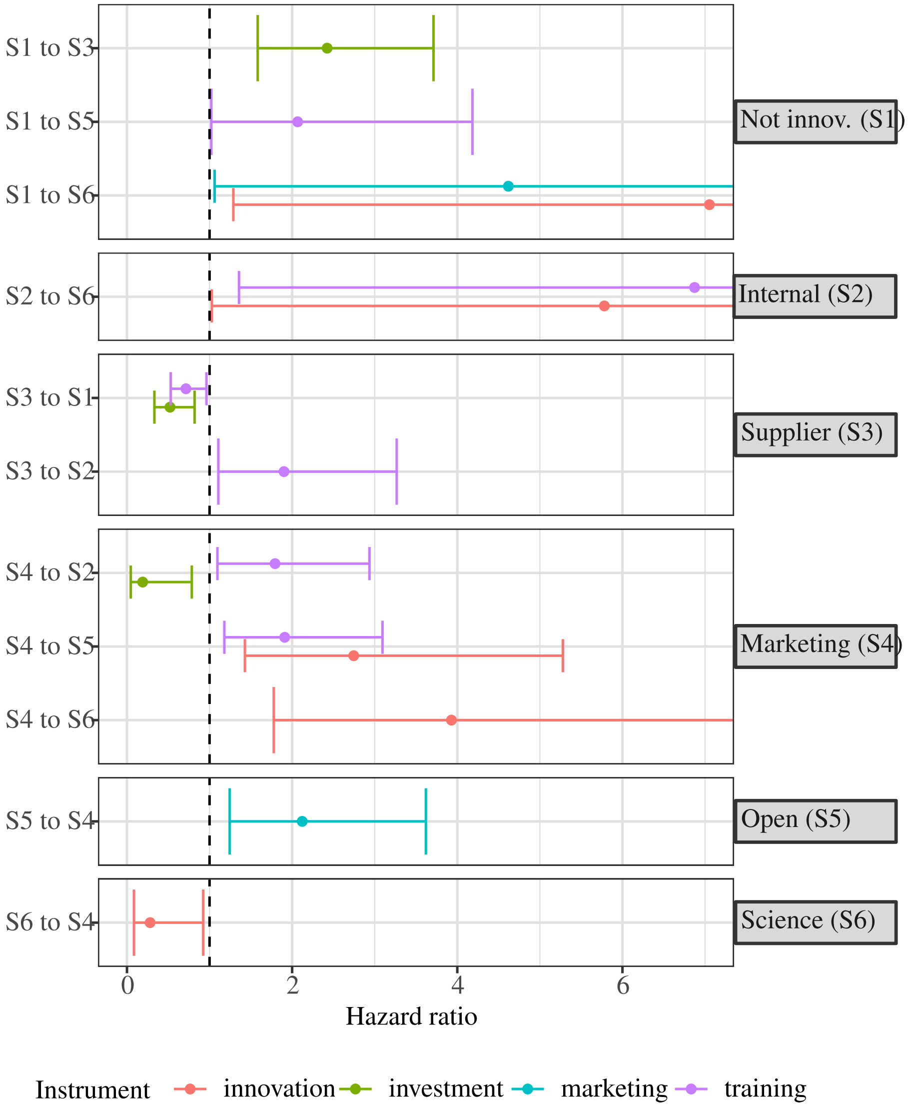
Transition	Innovation	Investment	Marketing	Training
State 1 to State 2	0 (0; Inf)	0.852 (0.206; 3.52)	0.533 (0.072; 3.913)	1.443 (0.64; 3.253)
State 1 to State 3	0.769 (0.106; 5.573)	1.595 (0.881; 2.888)	0.339 (0.083; 1.38)	1.115 (0.678; 1.834)
State 1 to State 4	0 (0; Inf)	0.504 (0.124; 2.056)	1.818 (0.724; 4.566)	0.951 (0.469; 1.93)
State 1 to State 5	0 (0; Inf)	0.893 (0.12; 6.661)	1.329 (0.175; 10.094)	0.754 (0.173; 3.284)
State 1 to State 6	0.005 (0; 5.537e+59)	0 (0; Inf)	0 (0; Inf)	2.641 (0.275; 25.386)
State 2 to State 1	1.726 (0.237; 12.587)	0.41 (0.055; 3.066)	0 (0; Inf)	1.154 (0.627; 2.126)
State 2 to State 3	0.735 (0.065; 8.306)	2.741 (0.712; 10.561)	1.179 (0.189; 7.372)	0.574 (0.221; 1.492)
State 2 to State 4	1.061 (0.193; 5.816)	0.826 (0.176; 3.884)	2.335 (0.703; 7.759)	1.242 (0.545; 2.832)
State 2 to State 5	1.043 (0.092; 11.839)	0.911 (0.106; 7.833)	1.671 (0.26; 10.755)	0.707 (0.242; 2.068)
State 2 to State 6	6.127 (0.27; 138.884)	1.818 (0.131; 25.206)	0.773 (0.031; 19.551)	4.226 (0.383; 46.619)
State 3 to State 1	1.742 (0.697; 4.357)	0.494 (0.271; 0.9)	1.103 (0.61; 1.996)	0.656 (0.424; 1.013)
State 3 to State 2	0 (0; Inf)	0.324 (0.076; 1.38)	0.908 (0.261; 3.155)	1.556 (0.718; 3.371)

Continued.

Continuation of table.

Transition	Innovation	Investment	Marketing	Training
State 3 to State 4	0.396 (0.055; 2.871)	1.259 (0.717; 2.209)	1.605 (0.834; 3.092)	1.01 (0.603; 1.694)
State 3 to State 5	0 (0; Inf)	0.629 (0.139; 2.852)	1.888 (0.488; 7.303)	1.536 (0.519; 4.54)
State 3 to State 6	0 (0; Inf)	1.107 (0.22; 5.56)	0 (0; Inf)	4.531 (1.246; 16.479)
State 4 to State 1	0.249 (0.06; 1.032)	0.831 (0.438; 1.575)	1.099 (0.613; 1.97)	1.113 (0.716; 1.731)
State 4 to State 2	0.51 (0.066; 3.945)	0.236 (0.032; 1.75)	0.482 (0.113; 2.064)	1.258 (0.578; 2.735)
State 4 to State 3	0.868 (0.338; 2.229)	0.969 (0.511; 1.839)	0.692 (0.341; 1.403)	0.845 (0.518; 1.379)
State 4 to State 5	3.127 (1.357; 7.207)	0.565 (0.196; 1.629)	1.222 (0.537; 2.78)	2.223 (1.1; 4.493)
State 4 to State 6	4.314 (1.377; 13.514)	1.786 (0.634; 5.033)	1.45 (0.501; 4.199)	0.547 (0.193; 1.55)
State 5 to State 1	0.901 (0.11; 7.363)	0.847 (0.105; 6.867)	0.344 (0.043; 2.776)	0.671 (0.209; 2.155)
State 5 to State 2	0.366 (0.048; 2.78)	1.405 (0.404; 4.883)	0.155 (0.02; 1.197)	1.806 (0.845; 3.861)
State 5 to State 3	0 (0; Inf)	2.259 (0.636; 8.02)	0.209 (0.027; 1.645)	0.6 (0.22; 1.633)
State 5 to State 4	1.403 (0.583; 3.373)	1.379 (0.596; 3.188)	1.779 (0.885; 3.576)	1.024 (0.534; 1.961)
State 5 to State 6	2.213 (0.538; 9.108)	1.098 (0.22; 5.47)	1.463 (0.413; 5.178)	0.934 (0.292; 2.983)
State 6 to State 1	0 (0; Inf)	0.797 (0.091; 7.018)	0.832 (0.083; 8.353)	1.728 (0.354; 8.437)
State 6 to State 2	3.565 (0.119; 106.522)	1.783 (0.06; 53.263)	5.351 (0.179; 159.806)	0 (0; Inf)
State 6 to State 3	0.678 (0.081; 5.705)	1.398 (0.281; 6.958)	0.414 (0.047; 3.62)	2.604 (0.674; 10.06)
State 6 to State 4	0.524 (0.12; 2.3)	0.936 (0.31; 2.823)	1.266 (0.422; 3.799)	1.488 (0.615; 3.604)
State 6 to State 5	0.476 (0.059; 3.826)	0.842 (0.177; 3.994)	1.524 (0.353; 6.579)	1.56 (0.455; 5.341)

XXV. Significant Hazard ratios for innovation policy instruments in the six-state Markov model



Significant hazard ratios for the six-state Markov model with the full dataset with exact transitions.

XXVI. State transition probability matrices for three-state Markov models

State transition probability matrix in 2, 6 and 10 years. Three-state Markov model with full dataset and exactly observed transitions. No covariates. Probabilities with 95% confidence intervals.

	t = 2 years; no covariates		
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,82 (0,8; 0,83)	0,16 (0,15; 0,18)	0,02 (0,02; 0,02)
Simple	0,24 (0,23; 0,26)	0,71 (0,7; 0,73)	0,05 (0,04; 0,05)
Complex	0,13 (0,11; 0,15)	0,28 (0,25; 0,31)	0,59 (0,55; 0,62)
	t = 6 years; no covariates		
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,65 (0,62; 0,67)	0,31 (0,29; 0,33)	0,05 (0,04; 0,06)
Simple	0,45 (0,43; 0,47)	0,48 (0,46; 0,5)	0,07 (0,06; 0,08)
Complex	0,35 (0,32; 0,38)	0,42 (0,39; 0,45)	0,24 (0,19; 0,28)
	t = 10 years; no covariates		
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,59 (0,56; 0,61)	0,36 (0,33; 0,38)	0,06 (0,05; 0,07)
Simple	0,52 (0,49; 0,54)	0,41 (0,39; 0,43)	0,07 (0,06; 0,09)
Complex	0,46 (0,43; 0,49)	0,41 (0,39; 0,44)	0,12 (0,1; 0,15)

State transition probability matrix in 2, 6 and 10 years. Three-state Markov model with full dataset and exactly observed transitions. Innovation and R&D, and training and skills development instruments given on years 3 and 4. Probabilities with 95% confidence intervals.

t = 2 years; innovation and training instruments on t = 3 and 4			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,82 (0,8; 0,83)	0,16 (0,15; 0,18)	0,02 (0,02; 0,02)
Simple	0,24 (0,23; 0,26)	0,71 (0,7; 0,73)	0,05 (0,04; 0,05)
Complex	0,13 (0,11; 0,16)	0,28 (0,25; 0,31)	0,59 (0,55; 0,63)
t = 6 years; innovation and training instruments t = 3 and 4			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,62 (0,52; 0,68)	0,29 (0,25; 0,37)	0,09 (0,06; 0,14)
Simple	0,39 (0,34; 0,44)	0,45 (0,41; 0,49)	0,15 (0,12; 0,2)
Complex	0,29 (0,25; 0,34)	0,39 (0,35; 0,43)	0,32 (0,26; 0,37)
t = 10 years; innovation and training instruments t = 3 and 4			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,57 (0,52; 0,6)	0,36 (0,33; 0,39)	0,07 (0,06; 0,1)
Simple	0,49 (0,46; 0,52)	0,41 (0,39; 0,44)	0,1 (0,08; 0,12)
Complex	0,43 (0,4; 0,47)	0,42 (0,39; 0,44)	0,15 (0,12; 0,18)

State transition probability matrix in 10 years. Three-state Markov model with full dataset and exactly observed transitions. Innovation and R&D, and training and skills development instruments given on every year (fully absorbed). Probabilities with 95% confidence intervals.

t = 2 years; innovation and training instruments fully absorbed			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,81 (0,63; 0,9)	0,13 (0,06; 0,25)	0,06 (0,03; 0,19)
Simple	0,15 (0,09; 0,23)	0,62 (0,51; 0,71)	0,23 (0,15; 0,32)
Complex	0,06 (0,03; 0,17)	0,19 (0,12; 0,28)	0,75 (0,62; 0,84)
t = 6 years; innovation and training instruments fully absorbed			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,59 (0,3; 0,75)	0,23 (0,12; 0,39)	0,19 (0,1; 0,41)
Simple	0,27 (0,15; 0,4)	0,37 (0,25; 0,49)	0,37 (0,24; 0,49)
Complex	0,17 (0,09; 0,34)	0,29 (0,19; 0,41)	0,53 (0,34; 0,66)
t = 10 years; innovation and training instruments fully absorbed			
	To:		
From:	Not innovative	Simple	Complex
Not innovative	0,47 (0,22; 0,7)	0,26 (0,15; 0,42)	0,27 (0,13; 0,48)
Simple	0,31 (0,17; 0,49)	0,31 (0,21; 0,44)	0,38 (0,23; 0,53)
Complex	0,25 (0,13; 0,45)	0,3 (0,2; 0,43)	0,45 (0,26; 0,6)

SUMMARY IN ESTONIAN - KOKKUVÕTE

Ettevõtete innovatsioonistrateegiate dünaamika ja seosed avaliku sektori toetustega

Innovatsiooni peetakse lahenduseks majandusraskustega võitlemisel ning on seetõttu olnud juba pikemat aega poliitikakujundamise tähelepanu objekt. Euroopas toetatakse eraettevõtlusest avaliku rahaga nii keskvalitsuste kui kohalike tasandite poolt. Eesmärk on kiirendada majanduskasvu toetades maksumaksja rahaga innovatsioonide teket ja levikut. Seetõttu on selline raha jaotus ka avaliku huvi osa ning tekib õigustatud küsimus, kas ja kui efektiivne on innovatsioonide toetamine?

Ettevõtete huvi on saada konkurentsieelis uusi tooteid ja teenuseid ehk innovatsioone luues. Ettevõtete sees ja neid ümbritsevas ettevõtluskeskkonnas on hulk tegureid, mis mõjutavad strateegilisi otsuseid koostada ja ellu viia innovatsioonistrateegiat (Rothaermel, 2017). Oskused, teadmised ja nende rakendamise viis võivad luua konkurentide ees pikaajalisi eeliseid takistades toodete ja teenuste kopeerimist. Ettevõtte valikud innovatsioonide loomiseks on osati ka piiratud võimalustega sektoritasandil (Nelson ja Winter, 1982; Winter, 1984). Sektorites kasutatavad tehnoloogiad määravad ära uute innovatsioonide otsimiseks võimaliku suuna nii tehnilisel tasandil kui nende loomiseks ja levitamiseks vajalikud ressursid. Siiski toimuvad mingi hetk sellistes tehnoloogilistes trajektoorides suuremad muutused, mis tervet sektorit korraga mõjutavad (Perez, 2009). Ühisosasid innovatsioonistrateegiates on leitud peale sektoritasandi ka ettevõttetasandil, kirjeldades strateegilistes valikutes tehtud sarnaseid otsuseid ettevõtetes sõltumata nende sektorist, vaid pigem innovatsioonide loomise viisist (Frenz ja Prevezer, 2012; Hollenstein, 2003; Leiponen ja Drejer, 2007; Pavitt, 1984).

Sellele vaatamata on teadmistes lüngad, kuidas muudavad ettevõtted oma innovatsioonistrateegiaid kui nad on saanud avaliku sektori poolt toetust innovatsioonipoliitika raames (Clarysse *et al.*, 2009; Georghiou ja Clarysse, 2006). Innovatsioonistrateegiaid on ettevõttetasandil korduvalt määratud (De Jong, Vanhaverbeke *et al.*, 2008; Leiponen ja Drejer, 2007; Pavitt *et al.*, 1989) ning ettevõtlustoetused[3] on olnud aastakümneid uurimise all (Dodgson ja Bessant, 1996; Martin, 2016; Salter

[3] Eesti keeles on seni levinud termin toetuste hulgas on ettevõtlustoetused, mis hõlmavad kõiki toetusi, mida ettevõtetele pakutakse sõltumata poliitikavaldkonnast.

ja Martin, 2001), kuid ettevõtlustoetuste võimalik mõju innovatsioonistrateegiate dünaamikale on olnud vähese tähelepanu all.

Doktoritöös toon need kaks teemat üksteisele lähemale. Doktoritöö eesmärk on hinnata ettevõtlustoetuste võimalikku seost muutustega ettevõtete innovatsioonistrateegias. Tegevused eesmärgi täitmiseks on järgnevad:

- Hinnata ja kirjeldada ettevõtete innovatsioonistrateegiad ja nende dünaamika
- Analüüsida ettevõtlustoetuseid innovatsioonide toetamiseks ning luua ettevõtlustoetuste taksonoomia Eesti näitel
- Hinnata seost ettevõtlustoetuste ja innovatsioonide kui väljundi vahel
- Hinnata seost ettevõtlustoetuste ja innovatsioonistrateegia vahel

Ettevõtete innovaatilisuse kasvatamiseks loodud poliitika ja meetmete üldine termin on innovatsioonipoliitika. Eestis on ka kasutusel olnud teadus- ja arendustegevuse ning innovatsioonipoliitika (TAI)[4] mõiste. Ideaalis hõlmab see tervikuna nii ettevõtluspoliitikat ettevõtete arendamiseks kui TAI poliitikat teaduse, teadus- ja arendustegevuse poliitikat, tehnoloogiapoliitikat ja innovatsioonipoliitikat (Lundvall ja Borrás, 2006). Doktoritöö raames on ühtlaselt kasutusel katusena mõiste innovatsioonipoliitka, mis hõlmab kõiki neid valdkondi korraga.

Põhjuseid, kas tasub poliitikameetmetega sekkuda eraettevõtete tegevusse nende innovaatilisuse suurendamiseks, on uuritud kaua. Põhilised argumendid võib jagada kolmeks. Neid võib ka kirjeldada kolme innovatsioonipoliitika lainena (Schot ja Steinmueller, 2018).

Esiteks turutõrgetel põhinevad argumendid. Näiteks on ettevõtetel raske kaitsta endi teadus- ja arendustegevuse tulemust konkurentide kopeerimise eest mistõttu jäävad osad projektid rahastamata (Arrow, 1962; Nelson, 1959). See aga vähendab heaolu kogu ühiskonna jaoks.

Teiseks innovatsioonisüsteemis erinevate osapoolte koostöövalmidus ja võimekus. Ettevõtted, teadus- ja arendustegevusega tegelevad asutused, kapitali võimendust pakkuvad asutused ja teised osapooled saavad üksteisele kasu tuua omavahel teenust pakkudes. Vähene koostöö ja võrgustumine innovatsioonisüsteemis takistab ettevõtetel oma potentsiaali rakendamist ning, taaskord, terve ühiskonna jaoks on heaolu kadu (Laranja *et al.*, 2008; Lundvall, 2010). Sarnaselt peale koostöövalmiduse on oluline aru saada ka võimekusest üksteisele teenust pakkuda ning vajadusel nõrgemaid osapooli järele aidata terve innovatsioonisüsteemi tugevdamiseks (Klein Woolthuis *et al.*, 2005).

[4] Tuleb ülekantuna inglisekeelsest *science, technology and innovation policy* ehk *STI*

Kolmandana on levimas uusim koolkond, mis argumenteerib innovatsioonide rollile ühiskonna jaoks oluliste probleemide lahendamisel (Mazzucato, 2015, 2018; Schot ja Steinmueller, 2018). Võrdluseks, esimesed kaks argumenti siiski eeldavad vaikimisi, et innovatsioonide loomise ja leviku roll ühiskonnas on majanduskasv. Uusima koolkonna argumendid juhinduvad ideest, et avalik sektor võib sekkuda pakkudes eraettevõtetele stiimulit uute lahenduste loomiseks väljakutsetele, mis ühiskonna jaoks on olulised. Seda kutsutakse üldjuhul missioonipõhiseks lähenemiseks, kus missioonid on väljakutsete raamistikud, näiteks linnakeskkonnas keskkonnasõbralikud transpordilahendused või kohaliku vesikonna keskkonnatervislik seisund. Missioonipõhine lähenemine on ka üheks aluseks järgmise Euroopa Liidu raamprogrammi rahastamisel, mis on üks suuremaid teadus- ja arendustegevust toetavaid meetmeid (Mazzucato, 2018).

Andmed ettevõtete innovatsioonistrateegiate kohta baseeruvad innovatsiooniuuringul (CIS), mida viib läbi Eesti Statistikaamet. CIS on Eurostati koordineermisel ühtlustatud uuring Euroopa Liidus ning seda viiakse läbi iga kahe aasta tagant. See tagab võrreldavuse teiste Euroopa Liidu riikidega. Eesti Statistikaamet tagab, et CIS oleks sektorite lõikes esinduslik üle 10 töötajaga ettevõtete kohta Eestis. CIS on maailmas kõige levinum küsitlusel baseeruv allikas ettevõtete käitumise uurimiseks innovatsioonide loomisel (Smith, 2005).

CISi andmekogule on lisatud andmed ettevõtlustoetuste, finantsnäitajate ning intellektuaalse omandi kohta. Ettevõtlustoetuste andmed on saadud otse kahelt Eesti suurimalt ettevõtluse toetustega tegelevalt asutuselt ehk Ettevõtluse Arendamise Sihtasutuselt (EAS) ja Põllumajanduse Registrite ja Infromatsiooni Ametilt (PRIA). Teiste Eestis ettevõtlustoetuseid pakkuvate asutuste andmed on kogutud Struktuurfondide registrist, mis hõlmab kõiki Euroopa Liidu Struktuurfondide vahendatud toetusi, ja Riigiabi registrist, mis hõlmab nii riigiabi kui vähese tähtsusega riigiabi. Viimaste alla kuuluvad kõik ettevõtlustoetused, millel on mõju konkurentsisituatsioonile, teisisõnu nad peaksid ettevõtet piisavalt mõjutama, et anda talle mingi konkurentsieelis.

Lisaks on CISi andmekogule lisatud Äriregistrist ettevõtete finantsnäitajad majandusaasta aruannete alusel. Täiendavalt on andmetele lisatud Eesti Patendiametist saadud andmed ettevõtete intellektuaalse omandi kohta, mis hõlmab patente, kasulikke mudeleid, kaubamärke ja tööstusdisainilahendusi.

Kogu ühendatud andmestik katab Eesti ettevõtteid vahemikus 2002-2012, kõiki teadaolevaid valimisse kuulunud ettevõtete saadud ettevõtlustoetusi ning on üldistatav kogu populatsioonile.

Uuritava perioodi sisse jääb Eesti liitumine Euroopa Liiduga, mis on märkimisväärselt mõjutanud innovatsioonipoliitikat, meetmete kujundust ja eelarvet. Põhilised argumendid avaliku sektori sekkumise õigustamiseks tulenevad esimesest ja teisest innovatsioonipoliitika lainest. Esmalt on vaja ettevõtetes innovaatilistust suurendada, et tekitada majanduskasvu. Põhiliseks mehhanismiks on uute toodete ja teenustega konkurentsieelise saavutamine välisturgudel ehk ekspordi suurendamine. Aastatel 2007-2013 on lisaks rohkem tähelepanu saanud erinevate osapoolte kokku toomine ja koostööd soosivad meetmed.

Võrreldes mõne enamlevinud ülevaatega Euroopas kasutusel olevatest innovatsioonipoliitika meetmetest (nt Edler ja Georghiou (2007) ja Izsak, Markianidou *et al.* (2013)) on Eestis üsna suur vaheldusrikkus ettevõtete otsetoetustes. Need on innovatsioonipoliitika meetmed, kus otsene kasusaaja on ettevõte. Innovatsioonipoliitika raames on lisaks veel võimalikud meetmed, mis toetavad mõnda teist innovatsioonisüsteemi osapoolt (Kuhlmann ja Arnold, 2001), nt teadlikkuse kampaaniad või haridus- ja finantssüsteemi mõjutavad meetmed. Doktoritöös on fookus selgelt otseselt ettevõtteid toetavatel meetmetel, mille mõju peaks konkreetselt uuritavale ettevõttele ka avalduma.

Seetõttu on peatükis 3 pikemalt lahti kirjeldatud Eesti ettevõtlustoetuste taust aastatel 2002 kuni 2012 ning välja toodud võimalikud argumendid avaliku sektori poolseks sekkumiseks. Sarnaselt Edler, Cunningham *et al.* (2016) meetodile on loodud tegevustel põhinev ettevõtlustoetuste taksonoomia, mis hõlmab kõiki valimisse kuulunud ettevõtete poolt saadud ettevõtlustoetusi.

Eesti ettevõtlustoetused saab loodud taksonoomia alusel jagada kümneks: koostöömeetmed; konsultatsioonid; koolitused ja oskuste arendamine; turundus- ja ekspordiplaanimine; innovatsiooni ja teadus- ja arendustegevused; investeeringud; tööjõukulude toetamine; finantsgarantiid ja laenukäendused; riiklik subsideerimine; ja segatoetused.

Peatüki 3 lõpus on kirjeldus, missugust ettevõttesisest innovatsiooniprotsessi need meetmetüübid kõige rohkem võiksid mõjutada.

Ettevõtete innovatsioonistrateegiad on hinnatud peatükis 6. Aluseks on võetud ettevõtete strateegilised valikud innovatsioonide välja töötamisel. Näiteks eelarve sisenditele nagu uue tehnoloogia hankimine, teadus- ja arendustegevus, töötajate koolitamine, koostöö- ja partnerlussuhted teiste osapooltega, intellektuaalse omandi kaitse, jne. Faktor- ja klasteranalüüsi kombineerimisel on 24 võimalikku strateegilist valikut taandatud iga ettevõtte kohta üheks tema strateegiat kirjeldavaks näitajaks. Sellist üldistavat näitajat innovatsioonistrateegia kohta nimetatakse innovatsioonimustriks (Castellacci, 2008).

Eesti ettevõtete innovatsioonistrateegiate analüüs viitab, et levinud on viis erinevat innovatsioonimustrit: tarnijapõhine, turupõhine, sisemiste ressursside põhine, avatud innovatsioon ja teaduspõhine.

Innovatsioonimustrid võtavad kokku viisi, kuidas ettevõtted innovatsioone teevad. Eristades omavahel ettevõtteid kasutatud teadmiste, tehtud tegevuste ja suhete innovatsioonisüsteemis alusel. Innovatsioonimustrid kirjeldavad ettevõtete innovatsioonistrateegiat.

Eesti ettevõtete innovatsioonimustrid on üldjoontes sarnased teiste Euroopa riikidega (vt nt De Jong ja Marsili (2006), Hollenstein (2003) ja Leiponen ja Drejer (2007). Välja saab tuua kaks eripära Eesti ettevõtete innovatsioonimustrite kohta, mida võrreldavates uuringutes pole seni täheldatud.

Esiteks on Eestis üsna väike osakaal teaduspõhistel innovatsioonimustritel. Need on ettevõtted, kes teevad majasiseselt rohkem teadus- ja arendustegevust ning tihedamat koostööd teiste asutustega, kelle põhitööks ongi teadus- ja arendustegevus, näiteks ülikoolid. Eestis on teaduspõhiste innovatsioonimustrite osakaal 6% kõikidest vaatlustest, kuid riikides, kus on võrreldavaid uuringuid tehtud, täheldatakse pigem 15%-20% suurust osakaalu. Eestis tervikuna ongi ainult suurusjärgus 250 ettevõtet, kes oma teadus- ja arendustegevust Eesti Statistikaametile raporteerib (Mürk ja Kalvet, 2015).

Teine Eesti eripära on selgelt eristuv innovatsioonimuster, mis põhineb sisemistel ressurssidel. Seda tüüpi ettevõtteid kirjeldab toetumine grupisisestele teadmiste allikatele ning grupisisene koostöö. Pärast innovatsioonimustrite hindamist lisatud välised andmed kinnitasid, et sisemiste ressursside põhistest ettevõtetest on 99% neist mingi ettevõtete grupi osad, põhiliselt tütarettevõtted. Sisemistel ressurssidel põhinev innovatsioonimuster viitab allhanke tüüpi suhetele, kus ettevõtted on väga selgelt spetsialiseerunud mingite konkreetse klientide teenindamiseks. Sarnast innovatsioonimustrit ei ole kirjeldatud üheski võrreldavas uuringus. Kahjuks ei ole võrreldavaid uuringuid tehtud teistes Kesk- ja Ida-Euroopa riikides, kus seda tüüpi suhted võivad olla rohkem levinud.

Innovatsioonimustrite dünaamika analüüs näitab, et ettevõtted on võimelised oma innovatsioonistrateegiat suhteliselt lühikese aja tagant muutma ning teevad seda tihti. Ettevõtteid, kes on järginud sama innovatsioonistrateegiat kümne aasta vältel oli 15%. Ülejäänud ettevõtted liikusid mingi hetk mõnda teise innovatsioonimustrisse ja vahel ka tagasi.

Innovatsioonimustrite dünaamika hindamiseks on minule teadaolevalt ainult üks võrreldav analüüs Šveitsi näite põhjal (Hollenstein, 2018). Sarnaselt Eestiga täheldab Hollenstein (2018) ettevõtete liikumist erinevate innovatsioonimustrite vahel üsna lühikese aja jooksul. Ta toob välja, et seda põhjustab Šveitsi ettevõtete väga kõrge konkurentsivõime, mis sunnib väga kiiresti optimeerima oma innovatsioonistrateegiat, et püsida maailma tippettevõtete hulgas. Innovatsioonimustrite vaheline liikumine on Eestis sarnaselt aktiivne, kuid Eesti ettevõtete innovatiivsus jääb selgelt alla Šveitsi omadele ja pole Euroopa Liidu parimate hulgas (Hollanders ja Es-Sadki, 2018; Hollanders, Es-Sadki ja Merkelbach, 2019). Seega vajaks selline innovatsioonimustrite dünaamika täpsemat teoreetilist selgitust, mis kirjeldaks paremini võimalikke muutusi kui dünaamiliste võimekuste mudel (Teece *et al.*, 1997).

Peatükkides 7 ja 8 on hinnatud ettevõtlustoetuste seost ettevõtete innovatiivsusega ja innovatsioonimustrite vahelise liikumisega regressioonmudelite alusel. Nende peatükkide alusel on välja valitud kõige olulisemate ettevõtlustoetuste tüüpidena investeeringud, innovatsiooni ja teadus- ja arendustegevused, turundus- ja ekspordiplaanimine, ja koolitused ja oskuste arendamine. Peatükis 9 on hinnatud Markovi ahelal põhinevate mudelite alusel nelja välja toodud ettevõtlustoetuste võimalikku seost liikumisega ühest innovatsioonimustrist teise.

Ettevõtete innovatsioonimustrid on jagatud kaheks: lihtsamad ja keerulisemad. Lihtsamad innovatsioonimustrid on tarnijapõhised, sisemistel ressurssidel põhinevad ja turupõhised. Keerulisemad on teaduspõhised ja avatud innovatsioon, sest nad nõuavad mitmetahulisemaid ning kulukamaid teadmisi, oskuseid ja ettevõttesiseseid protsesse.

Ettevõtlustoetuste ja innovatsioonimustrite vahel liikumiste seoste analüüs näitab, et toetuste abil ei võta mitteinnovatiivsed ettevõtted üle keerulisemaid innovatsioonimustreid. Toimub järk-järguline areng, kus esmalt liigutakse lihtsamate innovatsioonimustrite suunas. Seda võib kirjeldada kui õppimisprotsessi, mis seab oma piirangud. Seega peaks ettevõtlustoetuste puhul arvestama potentsiaalse sihtgrupi praeguste tegevustega ning suunama toetused vastavalt. Kui ettevõtetel pole üldse innovatsioonikogemust, siis ettevõtlustoetused keerulisemate innovatsioonimustrite poole liikumiseks võivad jääda ettevõtete võimekuse piiridest välja.

Tulemustest selgub, et mõned liikumised innovatsioonimustrite vahel on oodatud suunaga. Näiteks investeeringute toetused on olulised ettevõtete liikumisel mitteinnovatiivsest tarnijapõhisesse innovatsioonimustrisse. Investeeringute toetamine on esimene samm, mis on seotud ettevõtete liikumisel mitteinnovatiivsest staatusest lihtsamate innovatsioonimustrite poole. Tõenäosus liikuda lihtsamate innovatsioonimustrite poole on investeeringutoetustega ettevõtetel 50% tõenäolisem.

Innovatsiooni ja teadus- ja arendustegevusele suunatud ettevõtlustoetused on seotud ettevõtete liikumisega lihtsamatest innovatsioonimustritest keerulisemate suunas, iseäranis teaduspõhise poole. Tõenäosus liikuda lihtsamatest innovatsioonimustritest keerulisemate innovatsioonimustrite poole on innovatsiooni ja teadus- ja arendustegevuse toetustega ettevõtetel rohkem kui kaks korda tõenäolisem, keskmiselt 160% kõrgem.

Sarnaselt on positiivne seos liikuda lihtsamatest innovatsioonimustritest keerulisemate suunas koolituste ja oskuste arendamisega seotud toetustega ettevõtetel. Kuid täpsemad hinnangud konkreetsete mustrite lõikes ei ole nii ühesed, mistõttu ei ole oodatav tulemus selge. Koolituste ja oskuste arendamisega seotud toetustega ettevõtted on väiksema tõenäosusega liikumas mitteinnovatiivsesse staatusesse. Seega võib sellistel meetmetel olla roll ärahoidmaks ettevõtete taandarengut.

Turundus- ja ekspordiplaneerimise toetustega ettevõtted ei olnud positiivselt ega negatiivselt seotud liikumistega erinevatesse innovatsioonimustritesse.

Ettevõtlustoetuste mõjude empiirilisel hindamisel peab arvestama mitme ohukohaga, mis võivad statistiliste mudelite hinnangutes tekitada nihkeid. Sisuliselt on toetuste mõju hindamisel uurimise all küsimus: mis oleks juhtunud ettevõttega siis, kui ta poleks toetust saanud? Kahjuks ei ole võimalik sellist tulemust samal ajal jälgida. Seega on ainukene võimalus hinnata toetust saanud ettevõtteid võrreldes neid sobiva võrdlusgrupiga. Nihkeid mudelite hinnangutes mõjutavad kõige rohkem võrdlusgruppide valik. Ideaalis koosneb võrdlusgrupp täpselt samasugustest ettevõtetest nagu toetust saanud ettevõtted, ainus erinevus oleks toetuse mitte saamine. Praktikas on selles väga keeruline veenduda. Kuna enamik toetused, eriti Eestis, on avatud väga suurele ettevõtete hulgale korraga, siis toimub enese-selektsioon. Mingil põhjusel üks osa ettevõtteid soovib toetust saada ja üks osa ei soovi. Kahjuks ei ole võimalik täpselt jälgida ega kindlaks määrata, mis tingis selle enese-selektsiooni. Seega on toetust saanud ettevõtete ja võrdlusgrupi ettevõtete vahel mingi süstemaatiline erinevus, olgu selleks näiteks juhtimisvalikud, ambitsioon vms, mis mõjutab toetuse saamist. Tõenäoliselt mõjutab see ka ettevõtte sooritust pärast toetuse saamist. See süstemaatiline erinevus loobki nihkeid statistilistes mudelites (Heckman, 1979). Seega võib ka eeldada, et doktoritöös esitatud tulemustes on mingil määral positiivne nihe ning ettevõtlustoetuste tegelik mõju on mingil määral madalam.

Doktoritöös kokku pandud andmestik ettevõtlustoetustest Eestis on üks kõikehõlmavamaid ning pakub võimaluse tulevikus sarnastel teemadel veel uurimisteks. Iseäranis huvitav teema edaspidiseks on seotud ettevõtlustoetuste koosmõjudega ehk poliitikameetmete kombinatsioonidega. Erinevate meetmete vastastikused mõjud on empiirilisel hindamisel olnud seni vähese tähelepanu all (Martin, 2016).

Lisaks on innovatsioonistrateegiate dünaamikas veel täpsemalt uurida võimalikke ühismuutujad. Doktoritööle lisaks on sarnasel meetodil tehtud seni mulle teadaolevalt ainult üks uuring Šveitsi andmetel (Hollenstein, 2018). Selgusetu on lisaks veel mitmete oluliste ühismuutujate roll innovatsioonistrateegiate vahetamistel nagu intellektuaalse omandi suhtes, ettevõtete suurus, majandustsüklite roll või juhtimiskvaliteet.

Kokkuvõttes võib väita, et mitmed loogilised ja soovitud suunad ettevõtlustoetuste ja innovatsioonistrateegiate vahel on Eesti ettevõtete andmetel leitavad. Ettevõtted tõepoolest liiguvad erinevate strateegiate vahel, nad teevad seda tihti, ning need liikumised on positiivselt seotud ettevõtlustoetustega. Tuleviku innovatsioonipoliitika jaoks on see positiivne nähtus.

Uute meetmete disainimisel tasuks arvestada sihtgrupi ettevõtete senise kogemusega innovaatilistel tegevustel. Liiga suured arenguhüpped ei pruugi olla võimalikud. Kuid, tulemused siin doktoritöös viitavad, et muutused ettevõtete käitumises võivad tekkida mõne aasta jooksul ning ettevõtted on valmis liikuma keerulisemate innovatsioonistrateegiate poole. Ettevõtlustoetustega on võimalik seda sihtgruppi mõjutada, mis peaks olema ka innovatsioonipoliitika eesmärk. Eksisteerib mõõdukas tasakaal, et mitte välistada ettevõtteid liiga keerulisena tunduvate tegevustega, tagades samal ajal piisavalt ambitsioonikad väljakutsed.

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