LUND UNIVERSITY
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Master's Program in Innovation and Global Sustainable Development

Changing practices of modes of innovation and interactions

in Estonian case

by

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Abstract: There is growing numbers of literature debating over effective types of innovation modes and interactions that generate innovation output and moreover economic growth. However, these studies are mostly based on the case of developed countries and only few studies cover developing or transition countries. Within this context Estonia is chosen as the most successful post-Soviet transition country that is catching-up to the level of European Union in terms of economic growth and innovation level within a relatively short period of time. Estonia went through major structural reforms, including accession to EU membership and implementation of sequential Research and Development and Innovation (RD&I) strategies to improve its economic performance in a sustainable way through enhancing its innovation capacity by increasing its expenditure on R&D and building up competitive infrastructure. Within this context, this thesis studies what modes of innovation and interactions were practiced in Estonian firms after its independence and how these modes of innovation have changed during the early (first wave 2002-2004) and late (second wave 2010-2012) stage of implementing RD&I strategies and joining EU. Supporting the findings of most studies, the effective innovation mode has changed from DUI mode to combined STI and DUI mode for product inoovation output while process innovation output keeps its significant relation with combined STI and DUI mode of innovation during the two waves. Also the shifts in effective interactions for innovation outputs are observed with drastic changes in non-technological innovation while both external and internal interactions is applied for technological innovation from the first wave to the second wave.

Keywords: Estonia, Post-Soviet transition, STI mode of innovation, DUI mode of innovation, Interactions, Technological innovation, Non-technological innovation,

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List of Abbreviations

CIS	Community Innovation Survey
DUI	Learning by Doing, Using, Interacting
GDP	Gross domestic product
GERD	Gross domestic expenditure on R&D
MarIO	Marketing Innovation Output
OrgIO	Organizational Innovation Output
PrdIO	Product Innovation Output
ProIO	Process Innovation Output
PST	Post-Soviet Transition
R&D	Research & Development
RD&I	Research and Development and Innovation
S&T	Science and Technology
STI	Science Technology Innovation

1 Introduction

Since the world economy has entered into a free market system, the knowledge replaced capital, innovation replaced tradition, and ideas replaced manual work as the main source of power and economic growth. Such transformation brought the idea of "knowledge-based economy" (Sporer, 2004). While knowledge has become the predominant resource of economy, learning has turned into the most important process of integrating new knowledge and competences that enhance the capacity of firms to produce innovations (Apanasovich, 2016). The most often used definition of innovation is that "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or relations" (OECD, 2005).

Indeed innovation is the outcome of learning and interactive process that takes place within or outside the firm. Yet, some authors support that firms innovate through formal use and exchange of codified and explicit knowledge extracted through investing in research and development (R&D) and science and technology (S&T) and interacting with centers producing new knowledge (Jensen et al., 2007; Fitjar and Rodriguez-Pose, 2013). Jensen et al. 2007 claim that firms should have prior skills and competences to successfully absorb the codified knowledge otherwise automatic absorption leads to effortless knowledge transfer. Thus, the availability of human capital specifically personnel with formal S&T qualifications is also important to generate and adopt new innovations (inbid.). All these features are referred to as science, technology and innovation (STI) mode of innovation and this mode relies mainly on science-based knowledge.

On the other hand, authors argue that innovation comes from the use and exchange of tacit and implicit knowledge which is referred to as learning by doing, using and interacting (DUI) mode of innovation (Jensen et al., 2007; Gonzalez-Perniaet al, 2014). This mode is defined as experience based user-driven mode that supports the innovation in compliance with market needs (Apanasovich, 2016). Although some studies find that either STI or DUI mode alone is effective for generating innovation, other studies (Jensen et al. 2007; Amara et al., 2008; Guo et al., 2010; Isaksen and Nilsson, 2013; Apanasovich, 2016) find that firms combining both STI and DUI modes of innovation are more likely to introduce new products than those relying on just one approach. In fact, these studies are mostly focused on technological innovation output (product and process innovation) in developed countries, such as Denmark, Norway, Canada, Sweden, Spain that had relatively stable economic and social development over half a century, and only few studies have covered non-technological innovation output (organizational and marketing innovations) with developing or transition countries - China and Belarus.

The STI and DUI modes of innovation are linked to different forms of interactions and such interactions facilitate innovation by fostering learning processes through the sharing of knowledge and information (Fitjar and Rodriguez-Pose, 2013). As firms do not always have all necessary competence internally, cooperation with other firms and R&D institutions play

an important role for firms' innovation performance (RD&I, 2007). In the mean time, the increasing costs and complexity of R&D, the shortening of technology life cycles, the increasing presence of knowledgeable suppliers and clients, and the growing diffusion of cutting-edge knowledge in universities and research laboratories call inevitably for inter-organizational interactions and networks (Saenz and Pe´rez-Bouvier, 2014). Thus, there is a growing interest in interaction networks and research on effective interactions that foster innovation has received more attention recently (ibid.). There are two interaction networks involving internal and external that share and diffuse tacit and codified knowledge to nurture learning process. However, the most studies focus on the impact of external interactions - customers, suppliers, competitors, universities, research institutions or commercial labs (Weber and Heidenreich, 2018) while neglecting the internal interactions.

Remarkably, most studies focus on the effective practice of modes of innovation or external interactions mainly for technological innovation in developed countries covering 1-year period. Considering the research gaps of the above mentioned studies, this paper aims to analyze the changing practice of effective mode of innovation and interactions of Estonian firms for both technological (product and process innovation) and non-technological innovation (organizational and marketing) outputs over the period 2002-2004 and 2010-2012. The main contributions of this paper lie in four areas. First, the limited number of studies analyzed the effect of modes of innovation and interactions in post-Soviet transition (PST) countries. Second, both effective modes of innovation and interactions are analyzed together in this paper whereas above mentioned studies focus separately. Third, the study involves both technological and non-technological innovations outputs as they complement each other. Last but not least, the comparative analysis is progressed to learn how Estonian firms changed their practice of modes of innovation and interactions during a decade of time when the country went through major restructuring and transition process, including joining European Union and implementing research and development and innovation (RD&I) strategy since 2002. The reason why I chose Estonia is that the country is outperforming among PST countries in terms of its economic index and innovation rank. Also it has managed to develop its economy from upper-middle income to high income within a relatively short period of time while catching-up with the Western European developed countries through application of new technology and knowledge imported from those high-tech countries (Lember and Kalvet, 2014). Although the paper focuses on the changing practice of effective modes of innovation and interactions in Estonia after the communist system, it is worth recapturing the historical development of the country.

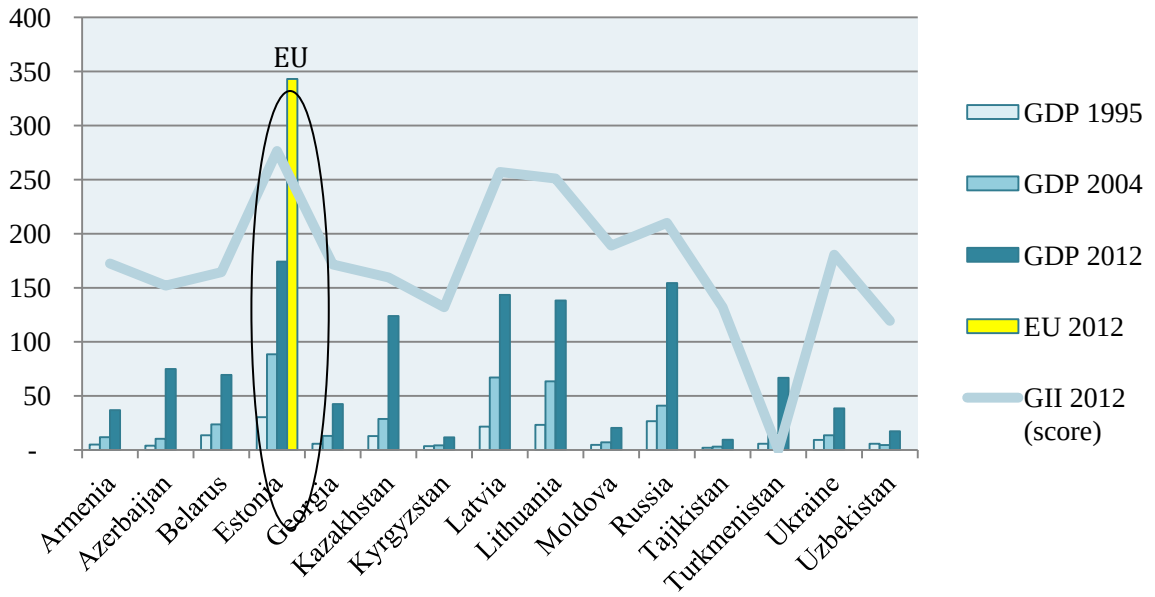
1.1 Estonia

In 1918, Estonia declared its own state and independence from Russia and Baltic Germans after a long struggle and was around similar economic level as Finland when Estonia was re-occupied by Soviet Union in 1940. Under the communist system, Estonian large firms had a high capacity of STI mode of innovation as they had their own laboratories, technical institutes and researchers that focused on applied R&D but, contrary to the free market economy system, these firms could not apply their research result at one's own and often the whole capacity of scientific research departments was not fully exploited due to long process of ministerial permission (Paasi, 2002). However, the much of these resources concentrated on

more military innovation than market innovation (Freeman, 1995) and the absence of strong interaction between commercial application and research results in the R&D institutes or departments negatively affected the transformation of R&D findings into innovation and further economic growth (Radosevic, 1998). Due to its vertical integration and supply-based system, the R&D activities were carried out mostly in specialized universities and research institutes but had a very low level of in-house R&D (Suurna and Kattel, 2010). In general, post-Soviet transition (PST) countries was highly industrialized and firms were built up and run in a complex web of planning and competition to fulfill the central plans of the Soviet Union (Vadi and Roots, 2004). Variety of cooperation and interaction networks existed, albeit there was no formal system to regulate the innovation-related networks due to linear innovation system (prioritizes scientific research as the basis of innovation) that neglected the need for interactive learning between the research and market-oriented development activities (Högselius, 2005).

Soon after the downfall of Berlin Wall, Baltic States were the first, followed by other 12 Eastern European and Central Asian countries, declared their independence and entered into a free market system in the early 1990s (Masso & Vahter, 2008). After 50 years of communism, Estonian per capita household income stagnated at level about six times lower than in Finland and that limited the purchasing power of domestic market (Mets, 2017). It was a quite painful transformation for the PST countries due to a fact that their institution and macro-economic policy need to be re-structured following the regime shift. Also they were isolated from the world's flows of trade and ideas and failed to diversify and to keep the pace with the latest technologies due to strict and inefficient communist system (Krammer, 2009). To overcome this hard time, Estonian government restructured the economic policies to liberal and open economy. Subsequently, when it comes to innovation and productivity, export-oriented firms have played important role to accelerate the catching-up process with the economic growth of Western European leading countries since 2002. It has been a long time since international trade is considered to be a source of knowledge transfer, especially when exports are directed to advanced economies or when firms export multiple advanced economies or when firms export multiple products to multiple destinations (Benkovskis et al. 2017).

In 2012, the European Union (EU) was the main destination for Estonian exports, especially neighbor countries Finland, Sweden, and other advanced European countries encouraged Estonian exporters to improve their product and service quality (Loecker, 2013). While Estonia became the most rapid PST country reduced its gap with EU income level by 50% during the period from 1995 – 2012 (Figure.1), the European Commission noted the Estonia as the European leader in innovation growth, followed by Lithuania and Latvia. These PST countries showed the highest rate of improvement despite being a long way behind the leaders. During the period 2008-2012, Estonian innovation performance increased with an average annual rate of 7.1% and it is followed by Lithuania and Latvia that improved at average annual rates of 5.0% and 4.4% respectively. Notwithstanding almost all EU member states improved their innovation performance, the overall EU annual average growth rate of innovation performance reached only 1.6% (European Commission, 2013). Today Estonia has been considered as the most successful PST catching-up economy that has permissive business environment with low burden of government regulation, low level of corruption, and good proximity location to the Nordic countries (Lember and Kalvet, 2014).



Sources: World Bank, Global Innovation Index (GII)

Figure 1. PST countries indexes, GDP per capita (current USD) and GII score

The various literatures support that Estonia had a high capacity of STI mode of innovation during the communist system but they could not exploit it due to closed and strong hierarchal innovation system that prioritized military innovation over market innovation. Under such centralized and strong hierarchies, even DUI mode of innovation and interactions were impossible to take in place due to its characteristic of relying on decentralized decision-making, softened hierarchies, eliminated strict boundaries between functions, and intensive teamwork (Apanasovich, 2016). For the sake of clarification, I should state that capacity of modes of innovation and interactions during the communist system is purely based on my assumption due to absence of literature covering the modes of innovation and interactions under the communist system. However, in this paper, I aim to analyze what effective modes of innovation and interactions Estonian firms have practiced and how it has changed during a decade under progression of implementing innovation strategy and accepting to EU membership since regaining its independence and entering into free market economy.

1.2 Outline of the Thesis

This thesis paper is structured as follows. In Section 2, the literature review provides overview of the innovation outputs, modes of innovation and interactions with relevant hypotheses. Section 3 presents the dataset, variables and method based on the large-scale of Community Innovation Survey (CIS) carried out in Estonia over the periods 2002-2004 and 2010-2012. Section 4 discusses insightful results of the econometric analysis of the data. In the final Section 5, the study summarizes the main conclusion, implications and suggestions for further research.

2 Literature Review

In this section, I cover three sub-sections – innovation outputs, modes of innovation, and interactions – that provide the current debate and discussions sourced from various literatures. At the end of the section research purpose is outlined by raising different hypotheses based on the Estonian re-structural changes and transition.

2.1 Innovation outputs

The firms can develop four types of innovations and they can be classified into two sub-categories: 'technological innovation' - product and process innovation, and 'non-technological innovation' – organizational and marketing innovation (OECD, 2005). Technological innovation tends to rely on investment in R&D and innovation infrastructures, while non-technological innovation relies on investing more in human capital that contributes rich inputs to the innovation process (Apanasovich et al., 2016). These four types of innovations are not isolated from each other as organizational and marketing innovations play crucial role in triggering product and process innovations of the firms and thereby increases their competitiveness.

2.1.1 Technological innovation

Technological innovation: First, "a *product innovation* is a new or significantly improved good or service that differs significantly from the firm's previous goods or services and that has been introduced on the market". Second, "a *process innovation* is the implementation of a new or significantly improved production process, distribution method, or supporting activities" (OECD, 2005). New innovations are considered as radical innovation that creates new market and obsolete existing products; and significantly improved means incremental or small and non-unique adaptation in a particular firm (Freeman, 1995). In its broadest sense, these two innovations tend to rely on STI mode of innovation and some authors argue that DUI mode can also lead to these innovations (Lorenz, 2012) albeit it has more impact on incremental or significantly improved innovations (Apanasovich et al., 2016).

2.1.2 Non-technological innovation

Non-technological innovation: First, "an *organizational innovation* is a new organizational method in the firm's business practices, including knowledge management (teamwork, flexible work arrangements), workplace organization (total quality management, business re-engineering) or external relations (outsourcing, networking, customer relations)". Jensen et al. (2007) highlight the importance of organizational innovation for product innovation

and advise that firms need to adopt organizational practices that promote knowledge exchange, problem-solving and learning amongst their employees besides their scientific and technological practices. Kurik et al (2002) finds that the innovative firms make organizational changes 2-3 times more frequently than the non-innovative firms. Second, "a *marketing innovation* is the implementation of a new marketing concept or strategy that differs significantly from the firm's existing method involving significant changes in product design or packaging, product placement, product promotion or pricing" (OECD, 2005). In contrast to technological innovation, these innovations are inclined toward more DUI mode of innovation than STI mode, and greater number of studies excluded these two innovation outputs from their analysis due to several reasons, such as less impact on firm's economic performance and output, database unavailability, etc.,.

Gonza´lez-Pernı´a et al. (2014) find that STI mode has stronger effects on product and process innovation through discovering and testing new properties, qualities, and configurations, while DUI mode impact more on organizational and marketing innovation through exchanges and interactions among workers, customers, competitors and suppliers. Similar findings supported by Parrilli and Elola (2012) who find higher correlation of STI mode with product innovation than the combined STI and DUI modes in Spanish firms. Notwithstanding the most studies cover more of technological innovation than non-technological innovation, this paper intends to involve all four types of firm innovation outputs to fill the gap of preceding studies.

2.2 Innovation modes

Indeed innovation is the outcome of different factors but, above all, knowledge and interactive learning are the predominant resource of innovative firms. Knowledge emanates from various sources, such as universities, research laboratories, organizations, training, customers, etc., and these knowledge are classified as codified and tacit that can be learned through two different modes of innovation - the STI (Science, Technology and Innovation) and the DUI (Doing, Using and Interacting). However, there is a strong debate over effective mode of innovation and it has attracted interest of many scholars in recently.

2.2.1 STI mode

After the industrial revolution, technological innovation has recognized as the main driver of enhancing competitiveness and capacity of firms that can further accelerate the economic growth of the countries. Several studies (Lundvall and Johnson, 1994; Freeman, 1995) highlight the importance of knowledge and learning process that improves the capacity of firms to innovate. Jensen et al (2007) introduce science and technology based innovation (STI) mode that relies mainly on science-based, codified, "know-what" and "know-why" types of explicit knowledge attained through formal R&D activities or universally accessible knowledge, such as from books, scientific articles or internet (Parrilli & Heras, 2016). Also STI mode is inclined toward more "formal relationship" with universities, research institutions and scientific researchers (Lundvall and Johnson, 1994). Even the European Commission and Parliament approved the Lisbon Agenda 2000 that determined the higher expenditure on private and public

R&D as a crucial driver of innovation and sustainable economic growth (Gonza´lez-Pernı´a et al. 2014). However, the numbers of limitations have been identified in STI mode and some empirical studies find the certain countries (i.e. Norway, Denmark) with low R&D investment but high economic and innovation output performance (Asheim & Parrilli, 2012).

2.2.2 DUI mode

The reason behind such contradiction of STI mode of innovation is recognized and further developed by several authors (Lundvall and Johnson, 1994; Asheim et al., 2012, Jensen et al., 2007) who find that implicit and tacit knowledge are the complementary key factors that improve the absorptive capacity and impact of R&D activities. This is called learning-by-doing, using and interacting (DUI) mode of innovation. According to the study of Apanasovich (2016), the concept of learning-by-doing implies that a firm performs experiential learning and increases productivity and efficiency by getting more practice and repeating the same operations. Learning-by-using relevant state-of-the-art technologies helps to acquire competences to increase the productivity of machines and learning-by-using user experience creates opportunities for experimentation and problem-solving on the shop floor (Lorenz, 2012).

Unlike the STI mode, this mode emphasizes informal and formal cooperations with customers, suppliers and competitors, and much less research intensive than STI mode (Fitjar & Rodriguez-Pose, 2013). Furthermore, DUI mode concentrates on mainly work-through experiences, "know-how" and "know-who" types of knowledge obtained through informal interaction as imitation and local buzz. Therefore, DUI mode of knowledge cannot be easily written or codified and that gives some advantages of preventing the knowledge to be leaked to competitors and that makes it more attractive than STI mode (Aspanovich, 2016**)**. While science and technological knowledge have been increasingly codified, much of practice in most fields remains in the individual scientist's memory as tacit knowledge (Jensen et al. 2007).

2.2.3 Combined STI and DUI mode

The number of authors support that DUI mode complements STI mode rather than compete against each other. That is because the strong DUI competency is needed for supporting the rapid development of codified scientific or technical knowledge that has become increasingly important for all kinds of businesses (Apanasovich, 2016). The STI and DUI modes of innovation are rarely found in pure forms in specific industries albeit industries can be dominated by either the STI or the DUI mode, for example STI mode tends to dominate in research-oriented industries such as nanotechnology, biotechnology, pharmaceuticals, and software that develop more radical innovations than DUI mode which prevails in more tradititional industries, such as textiles, furniture, machine tools, cars, etc,. (ibid.)

Radosevic (2006) states that it is crucial to effectively create, acquire, distribute and use the both codified and tacit knowledge to have high innovation output and economic growth in knowledge-based global economy. Following the study of Jensen et al. (2007) in context of Denmark, Amara et al. (2008) on Canada, Guo et al. (2010) on China, Isaksen and Nilsson (2013) on Norway and Sweden, and Apanasovich (2016) on Belarus confirm that combination of two modes of innovation promotes higher innovation than applying single mode of

innovation within the firm because it generates more scientific knowledge while stimulating stronger business interactions that enrich the innovation output. Yet some studies support that single mode has more effective than combined mode, such as the USA, Japan and Sweden practice more STI innovation mode whereas Denmark and Norway, among others, tend to apply more DUI mode as the key inputs for innovation. This set of contrasting results may indicate country-specific propensity to a certain modes of innovation (Parrili and Heras, 2016).

2.3 Interactions

Lundvall (1995) claims that innovation usually takes place when useful knowledge is able to be diffused and adopted in support of different organizational and institutional structures and interaction networks. Yet firms do not always have all necessary competence internally, and therefore, cooperation with other firms and research and development institutions play an important role for firms' innovation performance (RD&I, 2007). In spite of its different knowledge and learning approach, the STI and DUI modes of innovations are relied on transfer and spill-over of knowledge internally and externally of a firm (Weber and Heidenreich, 2018). Specially, a deep integration with external collaboration and partnership allows not only attracting new knowledge and technology, but also building research teams to boost innovation and productivity (EBRD, 2014).

Research on effective interactions that foster innovation has received more attention recently. Several studies have analyzed the impact of different types of interactions but mainly focus on external interactions with external R&D, customers, suppliers, competitors, universities, research institutions or commercial labs (Weber and Heidenreich, 2018) while neglecting internal interactions - in-house R&D and cooperation within firm. Several studies found evidence that interactions with customers, suppliers and competitors have a significant impact on firm's innovation output (Tomlinson, 2010; Peng et al. 2012). While interactions with supplier and customers are formal and aim to improve their competitiveness in the market, the interaction with competitors tends to be more informal and leads to knowledge spillovers that are more an unintended consequence of the relationship than its main purpose (Fitjar and Rodriguez-Pose, 2013). In respect of research based cooperations with universities, research institutions and commercial labs, some studies (Vuola and Hameri, 2006; Jia et al., 2010) support that this kind of interactions plays a crucial role for novel technological innovations. Gonza´lez-Pernı´a et al. (2014) claim that the interaction with universities would introduce more product innovation whereas the partnership with other research institutions tends to generate a process innovation.

Only few literatures cover all types of external cooperations and the effect of both internal and external interactions. In this study, two internal (inhouse R&D and within firm) and seven external (external R&D, universities, research institutions, commercial labs, customers, suppliers and competitors) interactions are examined to observe the changing practices of interactions on different innovations outputs and to compare the most effective type of interactions over the time. Out of fourteen innovation activities, nine activities are classified as internal and external interactions as mentioned above. The remaining innovation activities are

unclassified due to its nature of containing both types of interactions. The desciption of the interaction activities are available in Appendix A.

2.4 Research Purpose

Notwithstanding many scholars argue over the most effective innovation mode and interactions by studying certain country, industry and period, there is no literature covering the comparative studies reflecting on changing practices of innovation modes and interactions over the transition economic timeframe of a country. Estonia fits well for this study because the country is outperforming among the PST countries and is catching-up with Western European economic development and innovation level in relatively short period of time.

As means to elaborate accurate hypothesis on changing practices of innovation mode and interactions, it is worth considering the economic and social aspects of the country during the certain period of time. The study covers two weaves of period as following: first, the innovation practices of firms dating from 2002-2004, which called "the first wave" when Estonia was at the early stage of joining EU and implementing its first innovation strategy under linear model of innovation. In comparison, second, the period from 2010-2012 which called "the second wave" when the level of Estonian economy and innovation was at the later stage of progressing second innovation strategy and going through restructures of EU accession system.

2.4.1 First wave: 2002-2004

During the 1990s, in a great extent, the PST countries targeted to reach the level of Western-style capitalist economies through following its economic activities concentrated on the imitation and adoption of Western technologies, standards, rules and practices (Högselius, 2005). However, the technology push - "linear innovation model" was prevailed from early 2000s until mid 2000s (Tiits et al, 2008) and the innovations were mostly less-knowledge intensive. Further, the privatization process destructed the strong vertical integration between different actors and fragile economy negatively affected to weaken the capacity of STI mode of innovation due to dramatic reduction in investment on R&D activities, the number of researchers and the cooperation with research institutions (Paasi, 2002). Nonetheless, Estonia went through major structural reforms to improve its public governance and enhance competitiveness and also took crucial actions to improve the innovation competency and capacity of the firms.

At the end of 2001, Estonia defined its first "Knowledge-based Estonia: Research and Development and Innovation Strategy 2002-2006" (RD&I 1) based on Finish example. The very ambitious objectives were defined to update knowledge pool and increase the competitiveness of Estonian firms, such as increasing the gross domestic expenditure on R&D (GERD) to 1.5 percent of gross domestic product (GDP) by 2006. Also they adopted location-based policies, created science parks and regional business incubators and used international cooperation not only to attract foreign knowledge and technology, but also to build research teams avoiding "brain drain" (EBRD, 2014). However, the strategy had mixed outcome due to the fragmented innovation system as a whole, resulting considerable coordination problems in strategy design

and implementation together with insufficient policy appraisal, evaluation and monitoring systems (Suurna and Kattel, 2010). In 2006, GERD accounted for 1.13 percent of GDP and that shortfall in financing prevented from launching national R&D programs in key areas and increasing the number of graduate and postgraduate students substantially (EBRD, 2014). However, growth in corporate R&D accounted 44 percent of GERD, exceeded its target and foreign R&D investment increased from 13 to 16 percent while the EU average was average of 7 to 8 percent (ibid.).

On the other hand, it is widely accepted that PST countries inherited a large stock of tacit knowledge embodied in human capital that provided good growth prospects due to its effect on innovation process and ability to learn and to exploit external sources of technology (Paasi, 2002). The majority of firms engaged in process innovation through acquiring new machinery and equipment to become more and more cost-efficient in the free market place (Tiits et al, 2008). Such technological upgrading formed more firm based learning concentrated on adaptations to local conditions (Radosevic, 2006) and higher practical experiences and tacit knowledge by owing to their industrial specialization than that of formal R&D (Tiits et al, 2008). Lundvall (1994) points out the increasing importance of knowledge in the globalizing learning economy but Varblane et al (2010) criticized Estonia as they give much less attention to the absorption and diffusion of knowledge produced in the world. Thus, Estonia put much effort to improve its education quality and attainment and to reach higher level in tertiary-school enrolment than average of European Union nation states since 1995 (Figure 2). In the result, the high educational attainment and appropriate skill mix made Estonia well equipped to benefit from increased trade and openness (OECD, 2017).

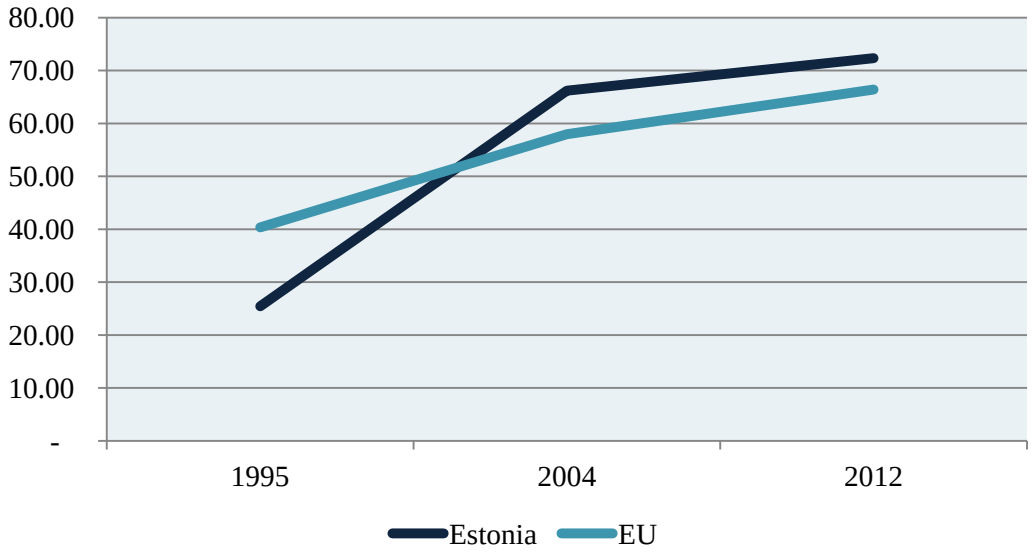
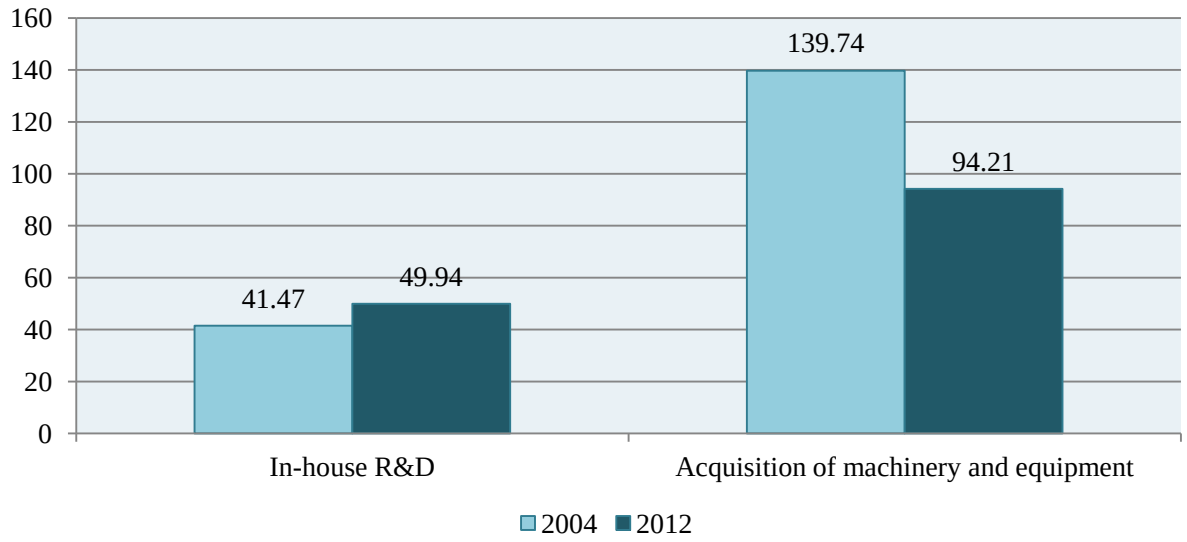


Figure 2. Tertiary education enrolment (% gross) *Source: World Bank*

Until 2002, Estonian economy growth was quite slow with average annual growth rate of 1.6%; and firms' innovation level was relatively low due to technological gap that was common issue for all PST countries where innovation activities were promoted by state support. Peculiarity of innovating firms in Estonian and other PST countries was that they spend much larger share of their total innovation expenditures for acquisition of machinery and equipment than the old members of the EU. In fact, the use of technologies, machines and equipment facilitates learning-by-using mode of innovation (Apanasovich, 2016). However, the share of in-

house R&D expenditure was still significantly low in Estonia (Terk et al. 2007). Consequently, Estonian firms operated behind the technology frontier and innovated through investing over three times higher in acquisition of basic machinery, equipment and software than in-house R&D in 2004 (Figure 3).

Figure 3. Expenditure on innovation activities (mln, kroon) *Source: Eurostat*



According to Apanasovich et al. (2016), combining the acquisition of up-to-date machinery and technology with a highly educated human capital is more prone to a strong impact of the DUI mode on innovation output. On top of that free market economy allowed the countries and firms to decentralize its decision-making, to soften its hierarchies, to eliminate its strict boundaries between functions and to encourage its intensive teamwork (Apanasovich, 2016) and that are the prerequisite condition of practicing DUI mode of innovation and internal interactions.

Yet, during the early 2000, Estonia had a problem in aligning firms with the universities and other external parties of the innovation system in respect to its old communist system, albeit its higher education system was undergoing rapid changes (Koch et al, 2007). Thus, Estonia experienced not only lack of knowledge base and human resources for R&D, but also there was insufficient interaction between universities and research institutes (Suurna and Kattel, 2010). Within this regard, the following hypotheses are proposed that Estonian firms practiced more DUI mode of innovation than STI mode, and innovation outputs are impacted solely by internal interactions than external during the first weave: 2002-2004.

Hypothesis 1a. During 2002-2004, internal interactions have higher impact for both technological and non-technological innovations than external.

Hypothesis 1b. During 2002-2004, DUI mode dominates on generating both technological and non-technological innovations rather than STI mode.

2.4.2 Second wave: 2010-2012

In 2004, Estonia joined EU membership and the EU's impact on formal terms has been the most pervasive and detectable from the second "Knowledge-based Estonia: Research and Development and Innovation Strategy 2007-2013" (RD&I 2) that reflected on the objectives of EU Lisbon Strategy, such as increasing the total expenditure on R&D to 3% of GDP by 2013 (RD&I, 2007). The strategy was focused on three main objectives: (1) creating competitive and R&D intensive entrepreneurs that (2) bring new value to the global economy and (3) create innovation friendly sustainable society (Ülle, 2015). The measures for implementation and its planned actions clearly show that strategy targeted to improve more STI mode of innovation and interactions than DUI mode of innovation (Table 1).

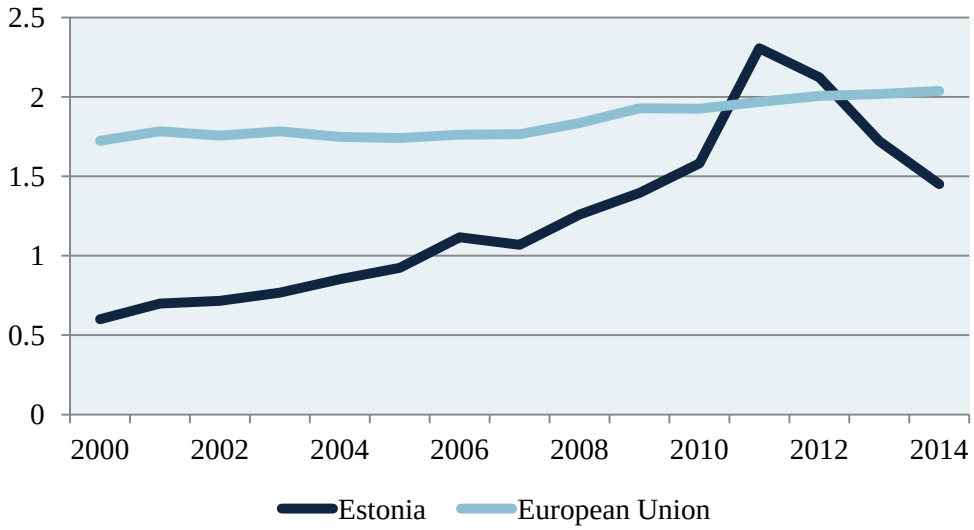
Table 1. Measures and planned actions of RD&I 2 objectives *Source: RD&I, 2007*

Measures for implementation of objectives	***Planned actions***
Development of human capital:	- Increase number of researchers and engineer per 1000 employees comparable with average of EU (8 to 1000) - Encourage the transfer of people and knowledge between educational and research institutions and firms
Organizing the public sector RD&I more efficiently:	- Promote world level research through the centers of excellence program - Support international cooperation networks between R&D institutions and firms and integrate into the work of international research organizations and facilities - Strengthen cooperation and specialization between universities and other research institutions and create network of core laboratories
Increasing the innovation capacity of enterprises:	- Increase the demand of enterprises for development and cooperation with universities - Develop attitudes and skills promoting entrepreneurship and supporting the commercialization of research results among the members of universities - Develop science and technology parks and incubators and make early stage equity investments
Policy-making aimed at the long-term development of Estonia:	- Increase measures and knowledge of the intellectual property activities - Stimulate the demand for new technologies within firms

Under RD&I 2 strategy, Estonia has upgraded its R&D and innovation system through restructuring their market economy and eliminating negative aspects of communist system. The

first phase of R&D infrastructure development program has started in 2006-2008 and the rate of R&D spending has drastically increased with total spending of 2.12% of GDP on R&D in 2012, the second highest after the first highest expenditure of 2.30% in 2011 (OECD, 2017). That happened mainly due to a doubling of the private sector R&D intensity, and which exceeded the EU average R&D expenditure (Figure 4). Under these strategies, Estonia went through a major structural reforms to improve public governance and enhance competition. In the result, Estonia successfully attracted trade and foreign direct investment that generated knowledge and innovation into the economy. A significant proportion of EU Structural Fund aid has been directed to the development of R&D infrastructure, human capital and entrepreneurship since accession to the European Union in 2004. In 2012, expenditure on in-house R&D increased by 20% while expenditure on acquisition of basic machinery, equipment and software reduced by 33% in comparison to 2004 (Figure 3).

Figure 4. Research and Development expenditure (% GDP) *Source: World bank*



During the same period transition and restructuring paradigm has replaced by the concept of converging to the average level of EU economy and society. The set criteria and support of EU had strong impact on new innovation regulation, policy and strategy in Estonia (Bruszt ,2002; Suurna and Kattel, 2010) that has changed innovation policy into modern innovation policy targeting innovation-system failures (Lember and Kalvet, 2014). At some extent, Suurna and Kattel (2010) explain that joining European Union (EU) had positive impact on the innovation policy of Central and Eastern European countries. The policy refers not only formal institutional adoption – innovation policy, strategy, and administrative capacity but also informal behavioral adoption – enforcement, application, and implementation of the formal adoption.

For developing new products and services, the innovation process turns into significantly complex one and that requires firms to improve their interaction networks (RD&I, 2007). Within this framework, Estonian government put a goal to support the interactions among firms, R&D and educational institutions, local governments, foreign partners and to help firms to make contacts with international competitors, suppliers and clients. In the result, firms were provided with modern conditions and attractive environment for R&D and broadened opportunities for external interactions (RD&I, 2014).

Further, Apanasovich et al. (2016) claim that firms in PST countries encourage organizational and marketing innovations mainly adopting Western managerial techniques and practices in interaction with different partners. By 2012, the European Union (EU) was the main destination for Estonian exports and neighbor countries Finland, Sweden, and other advanced European countries encouraged Estonian firms in a way of improving their product and service quality (Loecker, 2013). In brief, Estonia paid much attention to improve its STI mode of innovation and put priorities on ICT, health technology and services, and more efficient use of resources although the main sectors have been adjusted over time (EBRD, 2012). Since the peculiarity of non-technological innovation is inclined toward more DUI mode of innovation, the following hypotheses are proposed based on changes mentioned above.

Hypothesis 2a. During 2010-2012, external interactions have higher impact for both technological and non-technological innovations than internal.

Hypothesis 2b. During 2010-2012, combined STI and DUI mode dominates on generating technological innovations.

Hypothesis 2c. During 2010-2012, DUI mode still dominates on generating non-technological innovations rather than STI mode.

3 Methodology

This paper is based upon data from Estonian Community Innovation Survey (CIS) covering periods 2002-2004 and 2010-2012. The CIS is voluntary survey carried out by EU member states, candidate countries and number of ESS member countries mainly collected via online or mail surveys albeit some countries apply other collection methods as face to face interviews in frequency of every two years. The CIS data provides detailed information about the innovative sectors, the types of innovation and different aspects of influencing factors, such as objectives, sources of information, public funding or expenditures (OECD, 2005). The concepts and underlying methodology of CIS 2004 and CIS 2012 are based on the third Oslo Manual 2005 and used the NACE Rev.2 for classification of sample industries. The core population was drawn as a stratified random sample that covers firms with ten or more employees.

Estonian CIS 2004 and CIS 2012 datasets composed of anonymised information about 1747 and 1723 firms respectively. I restrict these data to the sub-samples of innovative firms for conceptual and methodological reason. As aforementioned in Section 2.4, the main interest of this study lies within the comparison of effective modes of innovation and interactions impacted on Estonian firms' innovation outputs between the first wave 2002-2004 and the second wave 2010-2012. Thus, to assess the firm-level innovation practices, I confined the dataset to the sub-sample of only innovating firms that introduced new or significantly improved technological (products and process) and non-technological (marketing and organisational) innovation outputs during the years. A firm is classified as innovating if it has introduced at least one out of four innovation outputs during the reference period. Given that 622 and 854 firms have zero total innovation output (sum of product, process, organisational and marketing innovations is equal to zero). I exclude them from the datasets and the final sample sizes used in the present study are substantially reduced to n=1125 and n=869 firms for empirical analysis of CIS 2004 and CIS2012 datasets respectively.

Notwithstanding the studies are within the same theoretical framework, their applied model is varied from one to another. In this study, I apply logit regression model for analyzing the effect of innovation modes and interactions for technological and non-technological innovation outputs. The logit regression is widely used statistical model in various fields that measure the relationship between the categorical dependent variable and one ore more independent variables by estimating probabilities using a logisitc function (Wikipedia). Thus, in this study, the following functions are used:

1. To assess the impact of interactions for innovation outputs:

$$logit(IO_t) = \alpha + \beta_1 iRD_t + \beta_2 eRD_t + \beta_3 aMach_t + \beta_4 aKnow_t + \beta_5 cUni_t + \beta_6 cCon_t + \beta_7 cReIn_t + \beta_8 MaRe_t + \beta_9 Des_t + \beta_{10} Tra_t + \beta_{11} cWF_t + \beta_{12} cCus_t + \beta_{13} cSup_t + \beta_{14} cCom_t + \varepsilon$$

where IO represents innovation outcome, t is time period, α is intercept, coefficients β_i are the parameters of the model, iRD is an indicator for in-house R&D, eRD is external R&D,

$aMach$ is years acquisition of machinery, *aKnow* is acquisition of existing knowledge, *cUni* is interaction with universities, *cComLab* is interaction with commercial labs, *cReIn* is interaction with research institutes, *cMaRe* is market research, *Des* is design, *Tra* is training for innovative activities, *cWF* is interaction within firm, *cCus* is interaction with customers, *cSup* is interaction with suppliers, *cCom* is interaction with Competitors and e is an error term. Descriptions of the variables are provided in Appendix A. CIS 2012 contains data of all these variables albeit CIS 2004 misses data on variable Design and, in fact, which can be interpreted as market research due to its relatively high correlation.

2. To assess the impact of innovation modes for innovation outputs:

$$logit(IO_t) = \alpha + \beta_1 DUI_t + \beta_2 STI_t + \beta_3 DUI\_STI_t + \varepsilon$$

where IO is innovation outcome, t is time period, α is intercept, β_i is the vector of associated coefficients, DUI is an indicator for DUI mode, *STI* stands for STI mode, DUI_STI is combined SUI and STI modes and e is an error term.

3.1 Dependent variables

There are four dependent variables: product, process, organizational and marketing innovation outputs (Table 2). Each dependent variable is composed from two to four innovation output indicators. In order to get the final variables with value of binary scale, the sum of each innovation output indicator is added together and categorized as following: *Product innovation* has two indicators, so if the sum of indicators is equal to 0, the there is ”No” (0) innovation but if the sum of indicators equals or above 1, there is ”Yes” (1) innovation; *Process innovation* and *Organizational innovation* have three indicators each, and the ”No” (0) is assigned when the sum of indicators is equal to 0, the ”Yes” (1) is set if the sum is equal or above 1. Finally, *Marketing innovation* has four indicators, and if the sum is equal to 0, there is ”No” (0) marketing innovation, otherwise ”Yes” (1) when the sum is equal or above 1. The explanation of each variable is shown in Table 2.

Table 2. Dependent variables

Variables	**Description**	**Binary Scale**
Product innovation		
– New or significantly improved goods – New or significantly improved services	if a firm introduced (1), otherwise (0)	No (0): sum=0 Yes (1): sum>=1
Process innovation		
– New or significantly improved methods of manufacturing or producing goods or services – New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services	if a firm introduced (1), otherwise (0)	No (0): sum=0 Yes (1): sum>=1

– New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing		
Organizational innovation		
– New business practices for organizing procedures – New methods of organizing work responsibilities and decision making – New methods of organizing external relations with other firms or public institutions	if a firm introduced (1), otherwise (0)	No (0): sum=0 Yes (1): sum>=1
Marketing innovation		
– Significant changes to the aesthetic design or packaging of a good or service – New media or techniques for product promotion – New methods for product placement or sales channels – New methods of pricing goods or services	if a firm introduced (1), otherwise (0)	No (0): sum=0 Yes (1): sum>=1

3.2 Independent Variables

Researchers use different typologies and methodologies for measuring indicators of innovation modes when they make empirical assesment. Indicators of STI mode have not changed much since they are introduced by Jensen et al. (2007) and the most commonly used and accepted 3 indicators are expenditure on R&D, number of scientifically trained personnel and cooperation with universities or scientific institutes. In contrast, the DUI mode has a diverse and heterogeneous indicators that categorized into each learning aspects – doing, using, and interacting. In this study, two groups of innovation activities are classified to identify STI and DUI modes under review of different studies (Jensen et al., 2007; Parrilli and Elola 2012; Gonzalez-Pernia et al. 2014; Apanasovich et al., 2016). First, there are five variables designated as indicators of the STI mode, including in-house R&D, external R&D, interaction with university, commercial labs, and research institutions (Table 3). R&D activity is considered as the key innovation input and is classified as in-house R&D and external R&D in CIS survey. The next three innovation activities are also crucial inputs, specifically interaction with university that allows information and knowledge spill-over between firms and external parties. The number of R&D personal with master or PhD degree in science and technology is widely used as STI mode indicator but this study do not include this indicator as CIS 2004 and CIS 2012 do not provide such data but only percentage of employees with tertiary degree in general.

Second, the DUI mode is composed from non-science based nine innovation activities, including acquisition of machinery, acquisition of existing knowledge, training for innovative activities, market research, design, interaction within firm, interaction with customer, suppliers, and competitors (Table 3). DUI mode indicators are quite diverse and heterogeneous that makes

it hard to measure and it evolves over time due to its component of informal interaction. Interestingly, these indicators are also classified as *learning-by-doing* (market research), *learning-by-using* (design), and *learning-by-interacting* (acquisition of both machinery and existing knowledge, training for innovative activities, interaction within firm and with customer, suppliers, and competitors). While the most studies focus and measure few indicators of DUI mode - specifically the learning-by-interacting with customer, suppliers, and competitors, this study covers various different indicators and the detailed description of these variables are attached in Appendix A.

Table 3. Independent variables. *Source: own elaboration*

Variables	**Description**	**Binary scale**
STI indicators		
In-house R&D External R&D	Engagement of the activity: Yes (1), No (0)	Not applied (0): sum=0 Applied (1): sum>=1
Interaction with university Interaction with commercial labs Interaction with research institutions	Cooperation partner by location: 5 different locations Yes (1), No (0)	
DUI indicators		
Market research Design Acquisition of machinery Acquisition of existing knowledge Training for innovative activities	Engagement of the activity: Yes (1), No (0)	Not applied (0): sum=0 Applied (1): sum>=1
Interaction within firm Interaction with customer Interaction with suppliers Interaction with competitors	Cooperation partner by location: 5 different locations Yes (1), No (0)	
STI_DUI indicators	Combination of STI indicators and DUI indicators	Not applied (0): sum=0 Applied (1): sum>=1

Repeating and improving practices of market research and commercial promotion activities encourage learning-by-doing, which in turn improves the related knowledge, skills and innovation capacity of the firm (Chen et al., 2011). Innovative design offers firms a competitive advantage that plays crucial role in differentiating its products and service from the competitors, and it is common to be invented based on learning-by-using. In terms of learning-by-interacting activities, the cooperation with customers, suppliers, and competitors are the most commonly used DUI mode indicators in different literatures (Chen et al., 2011; Parrilli and Elola, 2012; Fitjar and Rodriguez-Pose, 2013; Gonzalez-Pernia et al., 2014, Apanasovich et al., 2016). Interactions with different partners generates access to experience-based knowledge and information about markets and technologies (Lundvall, 2016). The other indicators are partly covered in some studies but not many studies include all these innovation activities all together as in this study. The CIS 2004 and CIS 2012 datasets allow to enrich the mythodology by adding new indicators - acquisition of both machinery and existing knowledge, interaction with

cosnsultants and commercial lab, and market research – contributing to broaden the learning-by-interacting indicators.

In order to analyze the STI and DUI modes, the sum of indicators in each mode is categorized into binary scale (0, 1). If the sum of STI or DUI indicators is equal to zero, that means no (0) innovation activity is applied within the firm. When the sum of STI or DUI indicators is equal or above 1, this indicates innovation activity has taken place (1) within the firm (Table 3). The detail information about survey format can be found in Appendix B.

3.3 Limitations of data

There is still no consensus on the drivers of innovation, neither on the impact of innovation on firm performance (Gonza´lez-Pernı´a et al. 2014). So it is hard to validate the effectness of independent variables, specially the DUI indicators that is complicated to capture through standard measurements due to its informal interaction within and between organisations (Harmaakorpi and Melkas, 2012). On top of that DUI mode is relativly new innovation approach so researchers have struggle with identifying appropriate indicators to measure its drivers and their output.

The CIS 2004 and CIS 2012 surveys lack few important variables used for measuring STI and DUI mode indicators, such as for STI mode indicator, no information is available regarding the employment of personnel with third-level degrees in science or technology. There is only general information about percentage of personnel with tertiary degree. In case of DUI mode indicators, several common activities from learning-by-interacting are not covered in the survey, such as the number of R&D department, organizational structure and interdisciplinary team or workgroups that Jensen et al (2007) applied for analysing Denmark case.

The last but not least, both CIS surveys provide unsufficient information regarding size of the firms that changed my initial plan to study only small-medium enterprises to avoid bias of small and big enterprises so that left me no better choice but to cover all sample innovating firms of Estonia.

4 Emprical analysis

Before going through the regression analysis, several descriptive analyses are examined to clarify the fit of datasets. In prevention from industry bias dominating in certain timeframe, descriptive table (Table 4) is formed to compare the number of industries in each mode. The classification shows almost same proportion of STI – 40% and DUI - 60% mode of industries in each weave : 2002-2004 and 2010-2012.

Table 4. Classification of industries *Source*: *own elaboration based on OECD (2011)*

	2004			**2012**		
	Freq.	Percent	Cum.	Freq.	Percent	Cum.
More STI (medium low – high tech)						
Chemical & Pharmaceutical	83	7.38	7.38	25	2.88	2.88
Electricity, gas, steam & air condition				16	1.84	4.72
Electronics & Machinery	49	4.36	11.74	91	10.48	15.20
Information & Communication	153	13.60	25.43	93	10.71	25.91
Metal, Rubber & plastic	51	4.53	29.87	100	11.52	37.43
Scientific R&D	80	7.11	36.98	35	4.03	41.46
Sum	**416**		**36.98**	**360**		**41.46**
More DUI (low tech)						
Accomodation & Food	42	3.73	3.73	76	8.76	8.76
Administrative & support	69	6.13	9.86			
Advertising & Marketing	47	4.18	14.04	19	2.19	10.95
Agriculture	82	7.29	21.33			
Apparel				41	4.72	15.67
Construction & Wholesale	27	2.40	23.73	62	7.14	25.11
Finance & Insurance	56	4.98	28.71	46	5.30	30.41
Furniture				41	4.72	35.13
Mining	87	7.73	36.44	12	1.38	36.51
Manufacturing	36	3.20	39.64	27	3.11	39.62
Wood, paper & printing				75	8.64	48.26
Real estate	61	5.42	45.06			
Transportation & storage	154	13.69	58.75	74	8.53	56.79
Water & Waste	48	4.27	63.02	35	4.05	60.84
Sum	**709**		**63.02**	**509**		**58.54**
TOTAL	**1125**		**100**	**869**		**100**

The descriptive data of the firms with (1) or without (0) innovation outputs shows that the number or innovative firms reduced greatly for PrdIO and OrgIO while ProIO and MarIO maintained its position (Table 5). Also the correlation between STI and DUI mode of indicators is examined and the results demonstrate that there is no significant correlations between STI and DUI indicators (Table 6). The absence of correlation means that the indicators of two modes do not share commonalities.

Table 5. Descriptive data on innovation outputs of the firms

	2002-2004								2010-2012							
	PrdIO		ProIO		OrgIO		MarIO		PrdIO		ProIO		OrgIO		MarIO	
0	442	39%	474	42%	353	31%	671	60%	430	49%	388	45%	481	55%	456	52%
1	683	61%	651	57%	772	69%	454	40%	439	51%	481	55%	388	45%	413	47%
Total	1125		1125		1125		1125		869		869		869		869	

Table 5. Correlation between STI & DUI indicators

2004

	STI_InhouseRD	STI_ExternalRD	STI_Universities	STI_CommercialLab	STI_ResearchInst	DUI_AcqTechno	DUI_AcqKnowhow	DUI_Training	DUI_MarketIntro	DUI_WithinFirm	DUI_Suppliers	DUI_Customers	DUI_Competitors
STI_InhouseRD	1												
STI_ExternalRD	0.343***	1											
STI_Universities	0.172***	0.243***	1										
STI_CommercialLab	0.173***	0.251***	0.590***	1									
STI_ResearchInst	0.118***	0.152***	0.589***	0.503***	1								
DUI_AcqMachinery	0.0452	0.0995**	0.0647	0.0483	-0.0111	1							
DUI_AcqKnowhow	0.284***	0.275***	0.196***	0.184***	0.124***	0.110***	1						
DUI_Training	0.278***	0.221***	0.135***	0.169***	0.125***	0.141***	0.269***	1					
DUI_MarketResearch	0.183***	0.145***	0.0940**	0.103**	0.0189	-0.0602	0.179***	0.119***	1				
DUI_WithinFirm	0.118***	0.239***	0.338***	0.345***	0.298***	-0.0654	0.116***	0.201***	0.0915**	1			
DUI_Suppliers	0.228***	0.289***	0.454***	0.491***	0.327***	0.0711*	0.202***	0.237***	0.108**	0.485***	1		
DUI_Customers	0.240***	0.283***	0.464***	0.465***	0.330***	0.0168	0.201***	0.207***	0.146***	0.427***	0.727***	1	
DUI_Competitors	0.168***	0.237***	0.441***	0.519***	0.406***	0.0619	0.170***	0.157***	0.101**	0.366***	0.591***	0.635***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

2012

	STI_InhouseRD	STI_ExternalRD	STI_Universities	STI_CommercialLab	STI_ResearchIns	DUI_AcqTechno	DUI_AcqKnowhow	DUI_Training	DUI_MarketIntro	DUI_Design	DUI_WithinFirm	DUI_Suppliers	DUI_Customers	DUI_Competitors
STI_InhouseRD	1													
STI_ExternalRD	0.374***	1												
STI_Universities	0.142***	0.158***	1											
STI_CommercialLab	0.133***	0.256***	0.332***	1										
STI_ResearchIns	0.0853*	0.0481	0.485***	0.272***	1									
DUI_AcqMachinery	-0.0365	0.0958**	-0.0181	0.0877*	-0.0384	1								
DUI_AcqKnowhow	0.356***	0.284***	0.129***	0.176***	0.0372	0.107**	1							
DUI_Training	0.0365	0.127***	0.104**	0.127***	0.00888	0.170***	0.272***	1						
DUI_MarketResearch	0.252***	0.156***	0.0100	0.0969**	-0.00527	-0.0248	0.126***	0.0827*	1					
DUI_Design	0.240***	0.149***	-0.0201	0.0583	-0.0410	-0.0286	0.0991**	-0.00607	0.450***	1				
DUI_WithinFirm	0.0914*	0.0769*	0.0343	0.147***	-0.0217	0.0376	0.109**	0.109**	0.0634	0.111**	1			
DUI_Suppliers	0.101**	0.110**	0.250***	0.219***	0.186***	0.0243	0.0947*	0.0703	0.0328	0.0136	0.0453	1		
DUI_Customers	0.0865*	0.124***	0.233***	0.295***	0.371***	0.0356	0.0669	0.0551	0.108**	0.00778	0.0113	0.149***	1	
DUI_Competitors	0.0252	0.0843*	0.162***	0.259***	0.165***	0.0514	0.0899*	0.0621	0.0280	0.0605	0.224***	0.113**	0.259***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.1 Analysing the effect of innovation modes and interactions on innovation outputs

As the dependent variables – innovation outputs of product (PrdIO), process (ProIO), organizational (OrgIO), and marketing (MarIO) – are binary (0, 1), the logit regression is conducted to test the effect of innovation modes and interactions on innovation outputs of the Estonian firms. Before analysing the individual coefficients of the model, the test of model-fit is checked in parameter estimates (Table 7 and Table 8). All chi-squares are significant at 0.001 level which means that null hyphothesis can be rejected. As indicated in section 3.2, there are 14 independent variables or innovation activities, including five STI indicators and nine DUI indicators. Not all but most innovation activities have significant impact on innovation outputs and their significance level have changed from the first wave 2002-2004 to the second wave 2010- 2012 (Table 7).

4.1.1 First wave: 2002-2004

During the first wave 2002-2004, some interesting patterns are observed as following. In most case, non-technological innovations are impacted by same innovation activities while technological innovations have reversed effect from the same activities (Table 7). In detail, the most significant and positive innovation activity for the product innovation output (PrdIO) is market research followed by interaction with customers and in-house R&D but the acquisition of machinery has significantly negative effect that is exacttly the opposite case for process innovation output (ProIO). Because the acquisition of machinery is the most effective innovation activity for ProIO followed by training and market research while interaction with customers have significantly negative impact.

In terms of non-technological innovation, same innovation activities – in-house R&D, market research, interaction within firm and with competitors - have sound effect for both organizational innovation output (OrgIO) and marketing innovation output (MarIO). On top of that, external R&D, acquisition of machinery and training are also significant for OrgIO whereas acquisition of existing know-how is signficant for MarIO. Notably, market research has significantly positive impact on all innovation outputs, except for ProIO, and that means learning about changing market needs and capturing market information enhance firm's capacity to innovate. When it comes to more effective interaction, external interactions – external R&D, interaction with customers and competitors - have higher impact than internal interactions – in-house R&D and interaction within firm - for all innovation outputs. That denies 1a hypothesis and means Estonian firms were already practicing more external interaction for their innovations during the 2002-2004. In case of dominating innovation mode, it varies from one innovation output to another (Table 8). All innovation outputs have at least two significant dominating innovation modes except for MarIO which has none. DUI mode dominates in PrdIO with slightly higher coefficiency than combined STI and DUI mode whereas the opposite is true for ProIO. Surprisingly, STI mode dominates in non-technological innovation – OrgIO while combined STI and DUI mode has significantly negative effect.

Table 7. Parameter estimates of innovation indicators

	2002- 2004				2010-2012			
VARIABLES	PrdIO	ProIO	OrgIO	MarIO	PrdIO	ProIO	OrgIO	MarIO
STI_InhouseRD - Int	**1.025*** **	0.143	**0.429*** **	**0.317** **	**0.463** **	**0.375***	0.124	-0.0355
STI_ExternalRD - Ext	-0.309	0.196	**0.502** **	0.230	**0.506** **	0.0307	**0.436** **	**0.424** **
STI_Universities - Ext	-0.0442	0.279	0.470	-0.479	-0.0671	-0.569	0.0219	0.273
STI_CommercialLab - Ext	0.134	0.235	0.0796	-0.216	-0.367	**1.139** **	0.489	-0.363
STI_ResearchIns - Ext	-0.724	-0.525	-0.000212	0.235	-	0.693	0.151	-0.631
DUI_AcqMachinery	**-1.447*** **	**2.024*** **	**0.398***	0.125	**-1.411*** **	**1.744*** **	-0.234	-0.264
DUI_AcqKnowhow	0.211	0.209	0.283	**0.291***	0.0470	0.115	**0.363** **	**0.601*** **
DUI_Training	-0.0921	**0.424** **	**0.386** **	0.263	-0.226	0.333*	0.106	-0.0120
DUI_MarketResearch	**2.200*** **	**-0.370** **	**0.370** **	**1.220*** **	**2.611*** **	**-0.889*** **	-0.143	0.280
DUI_Design					**0.645*** **	-0.221	0.0139	**0.940*** **
DUI_WithinFirm - Int	0.0551	0.287	**0.619** **	**0.417***	0.853	-0.0676	0.159	-0.426
DUI_Suppliers - Ext	-0.484	0.382	0.321	-0.146	0.298	-0.526	**1.057***	0.413
DUI_Customers - Ext	**1.054*** **	**-0.587***	-0.355	-0.177	1.093	0.430	**0.818** **	0.554
DUI_Competitors - Ext	0.233	0.177	**0.721** **	**0.613** **	0.460	-1.132	0.0379	**2.024***
Constant	1.420***	-0.988***	-0.756***	-1.455***	-2.303	-0.606	-3.359***	-2.817**
Chi-square	215.55***	146.93	125.26***	126.91***	324.57***	121.73***	45.18***	93.30***
Pseudo R-square	0.22	0.14	0.11	0.10	0.34	0.13	0.05	0.09
Observations	1125	1125	1125	1125	869	869	869	869

Table 8. Parameter estimates of innovation modes

	2002-2004				2010-2012			
VARIABLES	PrdIO	ProIO	OrgIO	MarIO	PrdIO	ProIO	OrgIO	MarIO
STI	0.174	-0.214	**0.814*** **	0.0643	-0.0447	**-0.883*** **	**0.558*** **	**0.552*** **
DUI	**1.133*** **	**0.984*** **	0.216	0.267	0.422	0.0562	-0.00927	**0.820*** **
STI_DUI	**1.101*** **	**1.216*** **	**-0.631** **	0.277	**1.278*** **	**1.727*** **	0.107	**-0.507***
Constant	-1.850***	-1.821***	0.816***	-1.024***	-2.080***	-1.302***	-0.819***	-0.925***
Chi-square	422.47***	370.94***	32.95***	42.37***	105.54***	87.10***	29.19***	39.21***
Pseudo R-square	0.28	0.24	0.02	0.03	0.09	0.07	0.02	0.03
Observations	1,125	1,125	1,125	1,125	869	869	869	869

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Thus, only PrdIO confirms 1b hypothesis and other innovation outputs reject the hypothesis 1b except MarIO during the first wave. It can be interprated that STI mode was more effectf for generating OrgIO than PrdIO, especially when it comes to introducing new methods of organising external relations with other firms or public institutions in OrgIO.

4.1.2 Second wave: 2010-2012

In the second wave 2010-2012, the similar patterns as the first wave are observed in both technological and non-technological innovation. Notwithstanding the number of significant indicators increased in PrdIO and MarIO, and decreased in OrgIO from the first wave to the second wave. As noticed in the first wave analysis, the technological innovations keep their reversal effect from same innovation activities in the second wave (Table 7). The market research is still the most significant innovation activity followed by design, external and in-house R&D. Also the acquisition of machinery keeps its significantly negative effect for PrdIO. The repeating opposite effects of market research and the acquisition of machinery for PrdIO and ProIO indicates that the probability to introduce new or significantly improved products increases when Estonian firms practice more market research activity but the probability decreases when firms acquire more machinery, equipment, software and buildings, and opposite is true for ProIO. In comparison with 2002-2004, the effective activities for PrdIO has changed from interaction with customers to external R&D and design; and for ProIO from training to commercial lab and in-house R&D.

On the other hand, effective activities for non-technological innovation have changed greatly from the first wave. Interaction with suppliers becomes the most effective innovation activity followed by interaction with customers, external R&D and acquisition of existing know-how for OrgIO. Similarly interaction with competitors has the highest impact for MarIO followed by other activities – design, acquisition of existing know-how and external R&D. Consequently, it is observed that effective activities for non-technological innovation is transformed into more external interactions, such as both innovation outputs have significanltly impacted by contracting out R&D and interaction with customers, suppliers, and competitors.

Overall, external interaction activities have more significant impact for both technological and non-technological innovations as signicance of external R&D is higher than in-house R&D for PrdIO, higher significance of interaction with commercial labs than in-house R&D for ProIO, and even no significant internal interaction but mainly external interactions for both OrgIO and MarIO during the second wave 2010-2012. Hence, the analysis leads to accepting the hypothesis 2a. The dominating innovation mode has changed for PrdIO and MarIO but no changes for ProIO and OrgIO in comparison with the first wave (Table 8). During the second wave, combined STI and DUI mode dominates on generating technological innovation which supports the findings of most studies that show evidence of stronger impact of combined mode on technological innovation and that accepts the hypothesis 2b. In terms of non-technological innovation, STI mode keeps its dominance and is the only significant effect for OrgIO. Unusually, MarIO has significant relationship with all three modes, and DUI mode dominates over STI mode while combined STI and DUI mode has significantly negative effect. Thus, only MarIO confirms hypothesis 2c but OrgIO rejects the hypothesis 2c in the second wave.

4.2 Comparison between first wave and second wave

Among all innovation outputs, the significant indicators of non-technological innovation show greater transformation practice than technological innovation. Specifically, the significant indicators of OrgIO shows radical changes from the first wave to the second wave. Organizational innovation encompasses a broad dimensions of structural and behavioral strategies such as workforce training, work design (more decentralized and flexible allocation of labor), external relations with partners and stakeholders (Mothe & Nguyen Thi, 2010). In case of Estonian firms, the innovation activities impacted for OrgIO has dramatically changed except for external R&D that remain as significant indicator over the years (Table 7). Such radical changes indicate how organization innovation is flexible and easy to be affected by different innovation activities whereas other innovation outputs are more sticky with certain innovation activities. Notably, both OrgIO and MarIO transit from its balanced reliance of internal and external interactions to extremely external interactions, such as significance of in-house R&D shift to external R&D, and interaction within firm shift to interactions with costumers, suppliers and competitors. Rust et al. (2004) claim that firms focusing attention on marketing innovations tend to have higher customer satisfaction than its competitors by adopting new market needs, exploiting business ideas and accessing new information and resources. All these happen when firms start learnning from external relations such as clients or competitors (Mothe & Nguyen Thi, 2010). Supporting these statements, Estonian MarIO keep its significant interaction with competitors during the both waves.

In contrast, the significant indicators of technological innovation have small but noticable transition to both in-house and external R&D activities. It is clearly shown in Table 8 that dominating innovation mode has shifted from DUI mode to combined STI and DUI mode for PrdIO which neglects the study of Parrilli and Elola (2012) who find higher correlation of STI mode with product innovation than the combined STI and DUI modes in Spanish firms. Whereas significant relationship of ProIO with combined STI and DUI mode of innovation during both weaves supporting the finding of Parrilli and Elola (2012). These results may demonstrate the effect of RD&I 2 strategy that increased expenditure on R&D in great extent during the second wave. In terms of non-technological innovation, the OrgIO has kept its significance with STI mode of innovation which ignores the finding of Gonza´lez-Pernı´a et al. (2014) who claim that DUI mode of innovation impacts more on organizational and marketing innovation while result of MarIO support their finding in the second weave.

Following Krammer's (2009) study, the result also shows that Estonia is lagging behind its Western counterparts when it comes to interaction with universities and research institutes which are insignificant for all innovation outputs. Such insufficient cooperation can be explained by the structure of the Estonian firms, where a large proportions of firms operate in low value added niche market (RD&I, 2007) or the failure in supporting the RD&I strategies at institutional level. Instead, other types of external and internal interactions have significant effect for all innovation outputs and that is perhaps in correspondance to the objective of supporting the development of cooperation networks between organizations to encourage growth of innovation under the RD&I 2 strategy.

5 Conclusion

As given that innovation is acknowledged as a key factor of sustainable economic growth and development, there are growing numbers of literature debating over effective types of innovation modes and interactions that generate innovation. Notwithstanding these studies mostly based on the case of developed countries, only few studies cover the case of developing and transition countries. Within this context Estonia is chosen as the most successful post-Soviet transition country catching-up with Western European economic and innovation level within a short period of time. During the communist system, Estonia had a high capacity of STI mode of innovation but low DUI mode of innovation and interactions due to its closed, centralized and strong hierarchal innovation system that prioritized military based innovation than market innovation. After regaining its independence, the capability of STI mode of innovation weakened along with significant cut in investment on R&D activities, the number of researchers and the cooperation with research institutions (Paasi,2002). Estonia went through major structural reforms, including joining to EU membership and implementing sequential research and design and innovation (RD&I) strategies. The strategies aimed to improve its economic performance in sustainable way through enhancing its innovation capacity by way of increasing expenditure on R&D, improving interactions with research institutes and building up competitive innovation infrastructure (RD&I, 2007). However, until this moment, it was unclear what modes of innovation and interactions Estonian firms practiced effectively for their innovation output and how it has changed over a decade period of time after going through the major structural reforms.

The comparative analysis explain certain changing practices of innovation mode and interactions over the time in Estonian firms; and I infer such changes as the impact from EU accession and RD&I 2 strategy implementation from the first to second weave. However, it has to be acknowledged that such discretionary powers of EU and RD&I strategy are bound and cannot be considered as complete factor for explaining the changes in innovation practices of Estonian firms. This paper attempts to analyze how Estonian firms have applied different innovation modes and interactions for their innovation outputs over the period of first wave 2002-2004 and the second wave 2010-2012. Supporting the findings of most studies, the effective innovation mode has changed from DUI mode to combined STI and DUI mode for PrdIO while ProIO has kept its significant relation with combined STI and DUI mode during the two waves. The shift in PrdIO can be explained in correspondence to implementation of RD&I 2 strategy when R&D expenditure reached its highest point - 2.31% of GDP in 2011 and second highest – 2.12% in 2012. From the regression result of mode of innovation, two things are found to be interesting to point out because two innovation outputs retained their relationship with one mode of innovation during the first and second waves. First, ProIO has the most significant effect with the combined STI and DUI mode despite of having insignificant STI mode activities during 2002-2004. Second, OrgIO is significantly impacted by STI mode albeit it is a non-technological innovation. Therefore these outcomes indicate that practicing STI mode activities, such as doing R&D and collaborating with research institutes, play significant role for OrgIO while practicing combined STI and DUI mode of innovation has more significant effect for ProIO than just practicing STI or DUI mode alone for Estonian firms.

On top of that the shifts in effective interactions for innovation outputs are observed with drastic changes in non-technological innovation while balanced (both external and internal) interaction is applied for technological innovation. During the first wave, both internal and external interactions have impacted the non-technological innovation significantly but internal interactions have turned into insignificant while the number of significant external interactions has increased during the second wave. When it comes to comparing the most significant type of interactions, external interactions always show higher impact on all innovation outputs than internal interactions during the both waves 2002-2004 and 2010-2012. Notwithstanding the most literature state that interaction with universities improves the innovation outcome of firms, the result of Estonian firms show insignificant relations with universities and that can be explained by the dominance of small size firms operate in niche market or the failure in supporting the RD&I strategies at institutional level.

From here, at least two relevant implications can be made based on these results. First, supporting the majority of studies on effective mode of innovation, Estonian firms have changed its practice of effective mode of innovation from DUI to combined STI and DUI mode of innovation in their technological innovation. Despite its weak STI mode capacity and two to three times lower expenditure on R&D than the expenditure on acquisition of machinery, the findings of Estonian firms support the practice of Western European developed countries where not only STI is important, but also DUI contributes to knowledge creation and innovation. Second, the most studies highlight the importance of external interactions without much evidence of comparing the effect with internal interactions and analyzing its effect mainly on technological innovation. However this study fills that gap and provides broader view with empirical analysis from the Estonian firms and adds new insights to the debate over such discussions. This could be useful for firms in another developing and PST countries when considering about applying effective innovation modes and interactions for improving their innovation capacity and competency as well as designing innovation strategy and policy.

5.1 Future Research

Community innovation survey has certain limitations within the scope of using datasets as indicators of STI and DUI modes that might lower the reliability of this study. However, that is the challenge faced by most researchers who have hardship to assess empricial typologies due to lack of standard indicators of the innovation modes, especially the DUI mode. Therefore, the future research could be improved by identifying reliable indicators, which are essential for high-quality empirical analyses. Especially, Estonian datasets do not provide proper information about size of the firms, number of R&D personal with master or PhD degree, or organizational structure (vertical or horizontal), etc,. Also using more carefully refined STI and DUI mode indicators, the application of a longer time span dataset capturing the dynamics of innovation would add robustness to the results.

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Appendix A

Classification of indicators into innovation modes and interactions

	Variables	Description
STI mode		
1	In-house R&D - *Internal*	Internal Research and development activities undertaken by firm create new knowledge or to solve scientific or technical problems
2	External R&D - *External*	R&D that firm has contracted out to other enterprises (including other enterprises in your group) or to public or private research organisations
3	Interaction with university - *External*	Universities or other higher education institutions
4	Interaction with commercial labs - *External*	Consultants and commercial labs
5	Interaction with research institute - *External*	Government, public or private research institutes
DUI mode		
	D (doing)	
1	Market research - *N/A*	In-house or contracted out activities for the market introduction of your new or significantly improved goods or services, including market research and launch advertising
	U (using)	
2	Acquisition of machinery and equipment- *N/A*	Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes
3	Design - *N/A*	In-house or contracted out activities to design or alter the shape or appearance of goods or services
	I (interacting)	
4	Acquisition of existing knowledge - *N/A*	Acquisition of existing know-how, copyrighted works, patented and nonpatented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes
5	Training for innovative activities – *N/A*	In-house or contracted out training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes
6	Cooperation within firm - *Internal*	Internal communication and co-operation
7	Cooperation with customer - *External*	Customers from both private and public sector
8	Cooperation with suppliers - *External*	Suppliers of equipment, materials, components, or software
9	Cooperation with competitors - *External*	Competitors in industry

Appendix B

2. Product (good or service) innovation

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.

- Product innovations (new or improved) **must be new to your enterprise**, but they **do not need to be new to your market**.
- Product innovations could have been originally developed by your enterprise or by other enterprises or institutions.

A **good** is usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods. A **service** is usually intangible, such as retailing, insurance, educational courses, air travel, consulting, etc.

2.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
Goods innovations: New or significantly improved goods (exclude the simple resale of new goods and changes of a solely aesthetic nature)	☐	☐	*INPDGD*
Service innovations: New or significantly improved services	☐	☐	*INPDSV*

3. Process innovation

A process innovation is the implementation of a **new** or **significantly** improved production process, distribution method, or supporting activity.

- Process innovations **must be new to your enterprise**, but they **do not need to be new to your market**.
- The innovation could have been originally developed by your enterprise or by other enterprises or institutions.
- Exclude purely organisational innovations – these are covered in section 8.

3.1 During the three years 2010 to 2012, did your enterprise introduce?

	Yes *1*	No *0*	
New or significantly improved methods of manufacturing or producing goods or services	☐	☐	*INPSPD*
New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services	☐	☐	*INPSLG*
New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing	☐	☐	*INPSSU*

8. Organisational Innovation

An organisational innovation is 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.

- It must be the result of strategic decisions taken by management.
- Exclude mergers or acquisitions, even if for the first time.

8.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
New **business practices** for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management, etc.)	☐	☐	*ORGBUP*
New methods of **organising work responsibilities and decision making** (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems, etc.)	☐	☐	*ORGWKP*
New methods of **organising external relations** with other firms or public institutions (i.e. first use of alliances, partnerships, outsourcing or sub-contracting, etc.)	☐	☐	*ORGEXR*

9. Marketing innovation

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.

- It requires significant changes in product design or packaging, product placement, product promotion or pricing.
- Exclude seasonal, regular and other routine changes in marketing methods.

9.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
Significant changes to the aesthetic **design** or **packaging** of a good or service (*exclude changes that alter the product's functional or user characteristics – these are product innovations*)	☐	☐	*MKTDGP*
New media or techniques for **product promotion** *(i.e. the first time use of a new advertising media, a new brand image, introduction of loyalty cards, etc.)*	☐	☐	*MKTPDP*
New methods for **product placement** or sales channels *(i.e. first time use of franchising or distribution licenses, direct selling, exclusive retailing, new concepts for product presentation, etc.)*	☐	☐	*MKTPDL*
New methods of **pricing** goods or services *(i.e. first time use of variable pricing by demand, discount systems, etc.)*	☐	☐	*MKTPRI*

5. Activities and expenditures for product and process innovations

5.1 During the three years 2010 to 2012, did your enterprise engage in the following innovation activities:

		Yes 1	No 0	
In-house R&D	Research and development activities undertaken by your enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement)	☐	☐	*RRDIN*
	If yes, did your enterprise perform R&D during the three years 2010 to 2012:			*RDENG*
	Continuously (your enterprise has permanent R&D staff in-house) ☐ *1*			
	Occasionally (as needed only) ☐ *2*			
External R&D	R&D that your enterprise has contracted out to other enterprises (including other enterprises in your group) or to public or private research organisations	☐	☐	*RRDEX*
Acquisition of machinery, equipment, software & buildings	Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes	☐	☐	*RMAC*
Acquisition of existing knowledge from other enterprises or organisations	Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes	☐	☐	*ROEK*
Training for innovative activities	In-house or contracted out training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes	☐	☐	*RTR*
Market introduction of innovations	In-house or contracted out activities for the market introduction of your new or significantly improved goods or services, including market research and launch advertising	☐	☐	*RMAR*
Design	In-house or contracted out activities to design or alter the shape or appearance of goods or services	☐	☐	*RDSG*

6.2 During the three years 2010 to 2012, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions?

Innovation co-operation is active participation with other enterprises or institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

Yes ☐
No ☐ **(Please go to question 7.1)** *CO*

6.3 Please indicate the type of innovation co-operation partner by location

(Tick all that apply)

Type of co-operation partner	[Your country]	Other Europe**	United States	China or India	All other countries
A. Other enterprises within your enterprise group	☐ *Co11*	☐ *Co12*	☐ *Co13*	☐ *Co14*	☐ *Co15*
B. Suppliers of equipment, materials, components, or software	☐ *Co21*	☐ *Co22*	☐ *Co23*	☐ *Co24*	☐ *Co25*
C. Clients or customers from the private sector	☐ *Co311*	☐ *Co312*	☐ *Co313*	☐ *Co314*	☐ *Co315*
D. Clients or customers from the public sector*	☐ *Co321*	☐ *Co322*	☐ *Co323*	☐ *Co324*	☐ *Co325*
E. Competitors or other enterprises in your sector	☐ *Co41*	☐ *Co42*	☐ *Co43*	☐ *Co44*	☐ *Co45*
F. Consultants and commercial labs	☐ *Co51*	☐ *Co52*	☐ *Co53*	☐ *Co54*	☐ *Co55*
G. Universities or other higher education institutions	☐ *Co61*	☐ *Co62*	☐ *Co63*	☐ *Co64*	☐ *Co65*
H. Government, public or private research institutes	☐ *Co71*	☐ *Co72*	☐ *Co73*	☐ *Co74*	☐ *Co75*