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COMPLEMENTARITIES IN PERFORMANCE BETWEEN PRODUCT, MARKETING INNOVATION AND CO-OPERATION WITH CLIENTS IN ESTONIA

Master's Thesis

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Name and signature of supervisor…………………………………………………

Allowed for defence on...

(date)

I have written this master's thesis independently. All viewpoints of other authors, literary sources and data from elsewhere used for writing this paper have been referenced.

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Abstract

This paper examines the complementary relationship between product innovation, marketing innovation and co-operation with clients in Estonian firms. The complementary relationship is evaluated with the effect on firm's performance measures, total factor productivity and turnover per employee. The cross-sectional sample is based on Estonian firms Community Innovation Survey (CIS) answers and Estonian Business Register data from years 2002-2012 and firms are divided into manufacturing and service industry. The regression analysis is conducted with Heckman selection model and the complementarity of studied actions is analyzed with supermodularity approach. It is found that product innovation and marketing innovation are substitutes in manufacturing industry and complementary in service industry. Co-operation with clients is complementary to product innovation in manufacturing industry and substitute to marketing innovation in service industry. Using panel data as robustness test, showed that total factor productivity indicator should be studied through time to see the complementary effects between co-operation with clients and the studied innovations.

Keywords: Product innovation, Marketing innovation, Co-operation with clients, Complementarity, Performance

JEL Classification: C13, D24, L25, O30

1. Introduction

Innovation is seen as one of the key drivers of economic growth in the last quarter of a century and therefore, there has been heavy investments to that field by firms and governments (Growth: Rationale…, 2007). Yet, there is a big difference in the results of investing into innovation between different firms (Hall, 2011). One of the reasons for that might be complementarity effect between different innovations. Oxford dictionary (2017) defines complementarity as “a relationship or situation in which two or more different things improve or emphasize each other’s qualities”. The economic framework of complementarity was first introduced by Edgeworth ([1897], 2001) in a footnote from a paper “La teorio pura del monopolio”. “The Prophet of Innovation” Schumpeter (1934) was one of the first researcher to argue that implementing certain innovation activities together can increase the total effect of innovation on the performance of the firm more than others. All of that gave way to different theories about complementarity and many empirical works studying the complementarity between different actions taken by the firm.

One of the most frequent innovation areas are products and marketing (Innovation Statistics, 2017). Marketing innovation and product innovation are closely related to each other, because marketing is done to sell more products or offer services to wider range of people and efficient and innovative marketing should increase that effect. Junge *et al.* (2016) found that in Danish skill-intensive firms product and marketing innovation together have higher positive effect on productivity growth than the effect of these two innovations separately. Therefore, they both should be complementary for each other and coordination between these two activities can be very beneficial for the firm.

Marketing is channeled towards finding new clients or selling more products to present clients. Product innovation is something that is meant to produce a good or service that gives more utility to the client. So, the main goal of both of these activities is to satisfy client’s needs. Logically marketing and product innovation should benefit from working together with clients and obtaining information about their needs and demands and then incorporating that information to the product and marketing activities. Indeed, the research has shown that co-operation with other firms, public sector or clients benefits the firms overall, even though the relationship between innovation and co-operation has not been that clear and the formal co-operation levels have been quite low (Miotti and Sachwald, 2003; Tether, 2002; Chesbrough, 2006; Cassiman and Veugelers, 2006). However, the positive effect of co-operation has been found to have curvilinear shape and excessive co-operation can have negative effect on the performance of the firm (Laursen and Salter, 2006; Berchicci, 2013).

Innovation Index 2017 ranked Estonia as the 25th most-innovative economy in the world and the top 25 includes only 2 relatively small countries beside Estonia, Iceland (13th) and Luxembourg (12th) (The Global…, 2017). However, Estonia has much lower GDP per capita of any of those 25 countries. In GDP per capita Estonia is in the 64th place (Country Comparison…, 2017). Knowing which innovation activities are complementary to each other can increase the positive effect of innovation and for a small innovative country and make a big difference in productivity and performance of the firm. Although this paper uses Estonia as its subject country, its results are also important for the overall study of innovations and co-operation with clients and complementary effect between them.

This research paper aims to find out if marketing innovation, product innovation and co-operation with clients have complementary effect on the firm performance. Additionally, we analyze how does the impact differ between industries and performance measure types. To achieve this goal the author has established following research tasks:

- to provide an overview of previously conducted empirical and theoretical research about innovation types, their effect on the performance of the firm and complementary effect between product, marketing innovation and co-operation with clients;
- to describe CIS and Estonian Business Register data;
- give an overview of the supermodularity approach to test complementarities;
- to find out the effects of marketing, product innovation, co-operation with clients and their complementarity on the performance of Estonian firms;

- to interpret the results and reach to the conclusion on the effects of marketing, product innovation and co-operation with clients on the Estonian firms performance.

There has been research to find complementarities between marketing innovation and product innovation (e.g. Junge *et al.*, 2016). There has also been studies that research the effects of co-operation with outside sources (e.g. Cassiman and Veugelers, 2006). However, there is not a lot of research that looks three type complementarities between innovations and other type of activities, especially between marketing, product innovation and co-operation with clients and their effect on the performance of the firm. This paper also contributes to innovation studies with connecting Community Innovation Survey (CIS) data with local business registry to have more precise performance data. This is not possible for many countries and that is why many innovation studies only rely on the answers of innovation surveys (Mairesse and Mohnen, 2010). In addition, the author uses two different performance measures, total factor productivity (TFP) and turnover per employee, to study how innovation and co-operation combinations affect differently the two performance measures. In this paper the author aims to find out through econometric analysis if marketing innovation, product innovation or co-operation with clients complement each other and add even more value to the firm together than separately.

The framework of this paper is as follows. Theoretical part starts with theoretical interpretation and overview of the empirical results of innovation and complementarity effect between different innovation types on the performance of the firm following the works of Junge *et al.* (2016), Brynjolfsson and Milgrom (2013), Milgrom and Roberts (1995) and Hall (2011) and others. This will continue with the description of the datasets and the descriptive statistics about the variables that we are using in the models and the author shortly writes about the limitations of the data. The next part will be methodology part with mathematical and econometric explanation of the models and supermodularity approach. The final part is dedicated to empirical results and interpretation of those results.

2. Literature review

This section of the paper gives a short and concise overview of the theoretical and empirical research about effects of innovation on the performance (henceforth “productivity” is used for the TFP measure and “performance” as wider term, which includes TFP, revenue or sales based measures) of the firm and different methods that are used for the analysis of the subject matter.

The study of complementarities between innovations tries to give explanation why different firms have different strategies and why quite similar firms still perform differently from each other. If complementarities between innovations exist, then it means that the decisions to implement different innovations should be inter-related with each other. Milgrom and Roberts (1995) have suggested in their paper that the success of the Lincoln Electric firm was due to complementarities between different inter-related choices of innovation and other activities that made it difficult for a big firm like General Electric to continue their activities in welding equipment business, because they could not keep up with the productivity of Lincoln Electric.

Teece (1986) showed with cluster analysis of innovators and followers-imitators that being an innovator does not guarantee bigger profits and better productivity than being a follower-imitator, if the innovators are missing some complementary activities. Therefore, complementarities between different actions can determine whether the firm succeeds even if the firm is an innovator.

Pisano (1990) and Brynjolfsson and Milgrom (2013) pointed out in their research that some innovation types are only beneficial to the firm when they are implemented together with other innovations. So with limited resources the budget should be spent with as efficient results as possible. Researching which innovations are complementary and implementing those innovations together can help firm to be more efficient with its budget.

Research tends to study the complementary effect of innovations from two main viewpoints. Complementarities in use approach studies which practices are implemented together and benefit from each other, and complementarities in performance approach studies how two or more practices together affect the performance of the firm (Colombo and Mosconi, 1995; Mohnen and Röller, 2005). Different authors have used different terms to indicate the same approach to study complementary effects. Complementarities in use approach is also defined as “CORR approach” by Athey and Stern (1998) and “Adoption approach” by Miravete and Pernias (2006). Complementarities in performance is also defined as “PROD approach” by Athey and Stern (1998) and “System approach” by Ennen and Richter (2010). In this paper the author will continue with terms “Complementarities in use” and “Complementarities in performance”.

With complementarities in use approach researchers study how different practices are linked and how they affect each other. This approach tries to answer questions about why some practices are usually implemented together or before some other practices and how they affect each other. For example, in some cases to innovate in products we first need to have new innovative machinery or process in place to even produce these new innovative products. Reichstein and Salter (2006) studied UK manufacturing firms and found that radical process and product innovation are complementary with complementarities in use approach i.e. firms that radically innovate in products are much more likely to also innovate their process. So complementarities in use approach only studies, which practices are implemented together to change one of the other practices easier to implement or benefit from. However, it does not guarantee that they are implemented together to increase the performance of the firm. They might be implemented together to increase the quality, variety, usability of the product etc., which should not affect the productivity of the firm (Brynjolfsson and Hitt, 2000).

To study how different practices together affect the performance of the firm, we need to use complementarities in performance method. Complementarities in performance approach studies how two or more practices together affect the performance of the firm differently than each of those activities separately. Ballot *et al.* (2015) explored the complementary relationship between product, process and organizational innovation and its effect on the performance of the firm in French and UK firms and found that there is complementarity between product and process innovation in both countries and complementary effect between organizational and product innovation in French firms only.

For this paper, the author will concentrate on studies that have used complementarities in performance approach, because the empirical part will study how complementarities affect the performance of the firm. However, to give more wholesome view of the subject matter, the author includes descriptive statistics about the implementation of innovations and co-operation in the beginning of empirical section of this paper.

Innovations and R&D are widely acknowledged as improving productivity of firms, but the productivity data has not always shown that (Brynjolfsson and Hitt, 2000; Brynjolfsson and Hitt, 1998; Roach, 1987; Solow, 1987). The “productivity paradox” was popularized by an American study by Roach (1987), where the investments to IT field grew a lot in the 1980s, but the results were not clearly present in productivity growth as expected. Brynjolfsson and Hitt (2000) showed through case studies and econometric analysis that the effect of IT investments is complementary to other parts of the firm and with firm-level data, we can see that the real benefit of IT investments is its complementary effect with other organizational assets, which result in new products and services and also better quality, variety, convenience and well-timed products, which are not represented in traditional measurements of productivity.

Several later empirical results show that product innovation increases the productivity of the firm, but the strength of the effect is mixed. Cassiman *et al.* (2010) showed with panel of Spanish manufacturing firms that product innovation positively affects the TFP of the firms and that process innovation does not have that effect on the productivity. Hall (2011) analyzed 25 different works about studying different aspects of product innovation effect on performance of the firm and found that product innovation has considerable positive effect on the performance of the firm. However, Parisi *et al.* (2006) found that the product innovation in Italian firms was not affecting the TFP as strongly as the process innovation. Working paper by Polder *et al.* (2010) concluded using CIS data for Netherlands that product and process innovations don’t have any effect of the performance of the firm without organizational innovations. The results of the papers seem to be highly influenced by the data and control variables that are added into the model.

There is not a lot of empirical research that studies only the effect of marketing innovation on the firm performance. Marketing innovation is usually studied together with other innovation or business activities. Nevertheless, most of the authors, who study the effects of innovation on the performance of the firm acknowledge the importance of marketing innovation (e.g. Narver and Slater, 1990; Gunday *et al.*, 2011). Some of the research about the effect of marketing innovation on the performance of the service enterprises has been done by Peters *et al.* (2015) and they found that in Germany, the UK and Ireland the market innovation is positively linked with labour productivity and the link is the strongest from all of the studied innovation and productivity links. However, Vahter and Masso (2012) did not find significant link between Estonian firms performance and marketing innovation in service industry, but they suggest that there should be more research done in that field.

In conclusion the effect of product innovation on the performance of the firm has been studied more thoroughly than marketing innovation's effect. Although both innovation types show to have positive effect on the firm, the effects have been with varying strength levels in different papers for individual countries and industries. Product innovation has also been shown to be affected by organizational innovation and process innovation.

Our paper studies the complementarity effect of product and marketing innovations. The positive relationship between those two innovation activities is logical, but there has not been a lot of academic research about how they affect each other and the performance of the firm. Gupta *et al.* (1986) researched relationship between product innovation and marketing, they came to a conclusion that when firms are innovating in some product field, they always face some uncertainty about how the product will be perceived by the consumers. Marketing interfaces can help to lower that uncertainty by integrating the product development with marketing (Gupta *et al.*, 1986). Junge *et al.* (2016) studied the effects of marketing and product innovation on Danish skill-intensive firms and found that the firms experience more productivity growth when marketing and product innovation are implemented together. They also found that when firms only participate in one of those innovation activities then they don’t experience any higher productivity growth than the firms that do not participate in neither of those innovation activities (Junge *et al.*, 2016). Therefore, marketing and product innovation may even be so closely related that firms benefit from them only if both are implemented, which is very similar to the point that Pisano (1990) and Brynjolfsson and Milgrom (2013) have made.

Of course, complementarities can occur between other aspects of the firm beside innovations, so in this paper the author has focused his work to find complementarities between product and marketing innovation and additionally the complementarity effect of co-operation with clients to those two innovations.

Innovations are new ideas or concepts that have been produced by somebody. So it would be rational to think that if the firm has more new ideas or concepts then there will be more innovations to choose from to produce and implement. And who would be best to give information about what the consumers need and how they want to acquire the product than the consumers themselves. Henry Chesbrough (2006) popularized the term “open innovation” and by that he meant using both internal and external inflows and outflows of knowledge to increase the internal innovation process and the effect of those innovations for the firm. Laursen and Salter (2006) found that the effect of openness on the performance is curvilinear (i.e. inverted U-shape) and therefore too much co-operation can have negative effect on the firm. The importance of external knowledge was also noted already by Von Hippel (1988) with an example of Japan user based firms replacing US supplier based firms in semiconductor manufacturing field in 1980s. Programmable technology companies have even taken co-operation with clients so far that they only provide the tools for customers and customers can become innovators themselves; the most famous case is IBM Linux open-source software, which can be modified by customers and IBM will only sell specialized software based on the customer modifications (Thomke and Von Hippel, 2002).

Jaworski and Kohli (1990) suggested and later (1993) found empirical proof that more market oriented firms have higher chance to successfully innovate in the product field and earn more premium from the sales of the innovations than firm that do not study and implement the market needs as much and that even holds in times of market turbulence and volatility. Berchicci (2013) found that external knowledge acquisition increases innovative performance only for firms that have smaller internal knowledge stock and with firms that have greater technological knowledge stock it will have substitution effect with innovative activities. This results goes in line with other theories and empirical findings that suggest market orientation can also limit innovation, because customers usually give the same information to different firms and in that case there can be only few innovations to implement based on the feedback from clients (Lawton and Parasuraman, 1980; Christensen and Bower, 1996). In addition, customers often even don't imagine that they would need products that are radically innovative, before they have been shown the new product (Tauber, 1974). There are multiple ways to look at the relationship of product, marketing innovations and co-operation with clients and the empirical results with different theoretic viewpoints are not conclusive in that respect.

Additional information about some of the main econometrical works studying complementary effects between different innovations and/or co-operation can be found from Appendix 1 of this paper.

From the literature review of innovations and their complementarity, we see that innovations are very important for the firm to be as productive as possible and that they also have different effects together with other innovations. The results and conclusions about the relationships and effects of innovation on the performance of the firm are mixed and highly dependable on the chosen data and methodology. That is one of the reasons why we should broaden the research with studying the effects of innovations in different countries and with slightly different methodologies to get more information what real effect of innovations and co-operation is for that specific region. Therefore, the next part of literature review is about the underlying methodology about how to evaluate the effect of innovations on the performance of the firm and how to test if they have complementary or substitutability effect together with other innovations or aspects of the firm.

One of the most influential models in innovation literature is CDM model, which plays a major part in many of the empirical works about the effects of innovation on the performance of the firm and has been used in some of the works that were previously mentioned (e.g. Arora, 1996; Gupta *et al.*, 1986; Peters *et al.*, 2015). CDM model was created by Crépon, Duguet, and Mairesse (1998) and is based on Griliches (1979) knowledge production function. CDM model takes the idea that R&D expenditures and productivity levels are indirectly connected with each other and divides the analysis into different stages. They generalize the stages into three relationships. Firstly, the relationship between R&D and its determinants. Secondly, relationship between innovation input/R&D and innovation output and finally, relationship between innovation output and productivity.

By using supermodularity test approach with Heckman model, we can get additional information about the complementary effects between innovations and co-operation with clients. Complementarity test with supermodularity approach was developed by Milgrom and Roberts **(**1995) using lattice theory and Edgeworth complementarity. The idea of the method is to divide different action situations into binary decisions and calculate, if implementing two or more actions together increases the output more than the sum of output increase of implementing either actions separately.

In a broad sense Polder *et al.* (2010) use the methodology of CDM model and supermodularity in their work about studying the effect of product, process and organizational innovation and their complementarity on the performance of the firm. The supermodularity approach is also used by Ballot *et al.* (2015) to study the complementary effects of the same innovations as Polder *et al.* (2010), but in a different framework model. The author combines different methods from both of these papers with additional analysis methods to add versatility to the empirical part of this paper.

3. Data and Descriptive Statistics

To analyze complementarities between innovations and co-operation with clients, we first need to answer the question: what is innovation? For that, we use OECD Oslo Manual, which was created in 1992 as a part of family of manuals to give an overview how data about science, innovations and technology should be collected, measured and interpreted. Since the first version of the manual, there has been few changes and in 2005 OECD, together with Eurostat, published the third version of the manual with which they added non-technological marketing innovations to the manual along with other changes. OECD Oslo Manual is the main information source for how innovation should be measured in European Union and some additional countries[1], so that the data would be harmonized and comparable between countries. The European Community Innovation Survey (henceforth CIS) is based on the definitions and rules of OECD Oslo Manual. (OECD Oslo Manual, 2005)

According to the innovation literature the main innovation types are: product innovation, process innovation, marketing innovation and organizational innovation (Schumpeter, 1934; OECD Oslo Manual, 2005). For this paper the author has chosen to follow more closely the concepts of product innovation and marketing innovation.

Product innovation means that the firm has introduced a good or a service that is completely new to the market or has significant improvements or changes made to the characteristics of the original product i.e. new material or components, new software, improved technical specifications or other functions (OECD Oslo Manual, 2005).

Marketing innovation means that the firm has implemented a new marketing method. New marketing method needs to have significant changes in at least one of the four P's of marketing, which are the design of the product package, product placement, product promotion and product pricing (OECD Oslo Manual, 2005; Kotler and Armstrong, 2010).

[1] According to CIS database the additional countries are Norway, Iceland and UK (after 29. March 2019).

The European Community Innovation Survey (CIS) was the first harmonized survey between countries from which Eurostat created micro level database. CIS is a survey conducted in European Union about innovation activities in firms, which questions are based on the Oslo Manual. Innovation activities include technological innovations, which are production and process innovation and also non-technological innovations, which are organizational and marketing innovation. There is addition information about co-operation with different information sources. The survey also collects information related to innovation activities. The survey started in 1992 and has been carried out with different time intervals. Starting from 2002 the survey has been conducted after every 2 years. (Glossary: Community…, 2017; Community Innovation…, 2017)

The author merges the Estonian firms' data from CIS to Estonian Business Register data to calculate different performance measures for each firm and their location. Based on the information of Estonian Business Register, the author calculates TFP with value added by the firm, number of its employees, materials and capital stock. Turnover per employee is also calculated based on the data of Estonian Business Register.

In the empirical part of this paper, the author uses CIS information about innovation activities from years 2002 until 2012[2], because starting from 2002, the survey included questions about marketing innovation. All the CIS-s have been pooled together to provide that the amount of data is enough for econometric analysis. The information taken from CIS-s and the Estonian Business Register that is used in the models is listed in Table 1.

The main division of the data is with groups, where firms have implemented at least one innovation type in the three year period of CIS and other group, where firms are doing innovation activities during the three year period, but did not implement any of them in that certain CIS period. In our data 60.9% of all the observations is for firms that have implemented at least one innovation type. For manufacturing firms the percentage of

[2] This period includes CIS 4, CIS 2006, CIS 2008, CIS 2010, CIS 2012

observations, where at least one innovation type is implemented is 63.4% and for service industry it is 56.9%.

Table 1. Descriptions and means of the variables used in the models for innovative firms and the whole sample (in italics and brackets)

Name of the variable	**Description**	**All firms[a] (6 411 obs)**	**Manufacturing firms (4 040 obs)**	**Service firms (2 371 obs)**
Implemented innovation	Firms that have implemented at least one innovation type (0,1)	60.9	63.4	56.9
Logarithmic TFP	Survey's last year logarithmic TFP of the firm	9.531 (*9.393*)	9.425 *9.354*)	9.723 (*9.462*)
Logarithmic turnover per employee	Survey's last year logarithmic turnover per employee of the firm	10.99 (*10.80*)	10.85 (*10.62*)	11.26 (*11.10*)
Start logarithmic TFP	Survey's first year logarithmic TFP of the firm	9.51 (*9.37*)	9.382 (*9.3*)	9.738 (*9.482*)
Start logarithmic turnover per employee	Survey's first year logarithmic turnover per employee of the firm.	10.93 (*10.80*)	10.75 (*10.59*)	11.26 (*11.16*)
Product innovation	If the firm has implemented product innovation during the survey period (0,1)	53.9 (*32.8*)	55.2 (*34.9*)	51.5 (*29.3*)
Marketing innovation	If the firm has implemented marketing innovation during the survey period (0,1)	45.4 (*27.6*)	43.7 (*27.7*)	48.2 (*27.4*)
Co-operation with clients	If the firm has co-operated with clients during the survey period (0,1)	19.6 (*11.5*)	19.3 (*11.8*)	20.4 (*10.9*)
Process innovation	If the firm has implemented process innovation during the survey period (0,1)	62.7 (*38.1*)	66.4 (*42.1*)	55.9 (*31.8*)
Organizational innovation	If the firm has implemented organizational innovation during the survey period (0,1)	54.2 (*33.0*)	50.2 (*31.8*)	61.3 (*34.9*)
Size	Logarithmic number of employees in the firm	3.88 (*3.68*)	4.02 (*3.8*)	3.62 (*3.5*)
Capital intensity	Logarithmic capital and labour ratio	9.01 (*8.85*)	9.09 (*8.85*)	8.85 (*8.84*)
North Estonia	Firms with main region as North Estonia (0,1)	56.1 (*54.6*)	45.7 (*45.2*)	75.5 (*70.0*)
Export	If the firm is exporting (0,1)	82.8 (*78.6*)	89.9 (*86.3*)	70.9 (*65.9*)
Group	If the firm belongs to a group (0,1)	51.3 (*42.5*)	48.8 (*40.1*)	55.7 (*46.1*)
EU average innovation activity[b]	EU average innovation activity by two-digit EMTAK2008/NACE sector dummies	0.354	0.391	0.286

[a] The author has excluded firms with less than 10 employees. [b] The author has excluded government, medical and teaching sectors. The binary variable results are in percentages.

Source: CIS and Estonian Business Register, calculations by the author

From Table 1, we can also see that overall innovative service and manufacturing industry observations have the same percentage range of product innovation, marketing innovation and co-operation with clients. Manufacturing industry has 3.7 percentage points more product innovation observations and service industry has 4.5 percentage points more marketing innovation observations. Co-operation with clients is almost the same for both industries with 19.3 percentage for manufacturing industry and 20.4 percentage for service industry. Although the studied actions (henceforth words “action” and “activity” both signify innovation or co-operation) have the similar percentage amounts by the industry sample, the sample sizes per industry type are quite different. From the whole sample 63 percent of the observations are for manufacturing industry and 37 percent are for the service industry. In addition, only a little bit more than half of those service observations indicate implemented innovations. That might be one of the reasons why the performance indicators are higher for service observations than they are for the manufacturing industry. There might be a case that we have only the strongest and better performing service industry firms from the whole Estonian population in our innovative firms sample.

From Appendix 2, 3 and 4, we see the descriptive statistics of the performance indicators of the firms used in this paper for all of the three studied action pairs. They are divided by the different activity combination dummies. Most of the observations are in the category, where none of the two studied activities are implemented and it is also logical, because almost half of our observations are about firms that did not implement any innovation types in the studied period. In the data, we don’t have any single dominating strategy for studied activities, but with including the information from Table 1, we can say that co-operation with clients observations amount is much smaller than product or marketing innovation observations amount. This can affect our results that are connected with co-operation with clients action, because the sample, where firms co-operate with clients is quite small (around 11% for the whole sample). From the means of performance indicators by action combination, we can’t see yet whether we have any complementary or substitutability effects, because no combination shows particularly large differences in average performance measure. To get information about complementarity, we first need to evaluate the model and then use supermodularity approach to test complementarity between the actions.

There are also several limitations and problems with the dataset that we have. One of those problems is that the CIS does not report the cost of the innovation and for the marketing innovation CIS does not also report the scale and the intensity of the innovation. For product innovation, we have field to report the share of new products in sales, however in our dataset the answer is different from 0 only for ~30% of the whole sample (although 60.9% of the firms have implemented product innovation). Therefore, we can’t separate whether the innovation had large or small effect on the firm and how much it cost to the firm to implement. This might create a situation, where most of the innovations are small scale and may not have as large effect on the firm performance and that is why innovations overall might not seem to have an effect on the performance even though, larger scale innovations might have larger effect on the performance of the firm.

Our data also has possible endogeneity problem, because we take observations as only in one period and therefore, have cross-sectional dataset. Endogeneity comes from the fact that we can’t control for causality problem to be sure that innovation activity affect the performance of the firm and not that performance of the firm affects the innovation activity of the firm i.e. we can have a reverse causality. Due to small sample size and different action dummy combinations, we can’t create panel data and have enough observations to interpret the results meaningfully for manufacturing and service sample separately. Therefore, the author conducts robustness test with panel data without separating by the two main industries. This robustness test gives more insights how the effects of innovations and co-operation change over time for the firms. Other problems and limitations that are more connected to methodology or are solved by using specific methodology are covered in more detail in the following methodology part of this paper.

4. Methodology

In this paper the author uses complementarities in performance with supermodularity approach methodology to test for complementarities between product and marketing innovations and co-operation with clients. For this the author first creates dummy variables for each combination of the studied activities. These combinations of dummy variables are shown in Appendix 2, 3 and 4 with performance measurements descriptive statistics.

For supermodularity approach we first take the four combinations of two activities. This means that we make dummy variable for when observation has none of the observed activities implemented, then two variables, where only one of the observed activities is implemented and then dummy variable for when both of the two observed activities are implemented. For example with product and marketing innovations, we will produce following dummies: firm has not implemented product and marketing innovation (0,0), firm has implemented only marketing innovation (0,1), firm has implemented only product innovation (1,0) and firm has implemented product and marketing innovation (1,1).

Before conducting the complementarity test, we need to find the effects of the action combinations on the performance of the firm. Because of the limitations of the data about Estonian firms that are reported in CIS and the gaps in the data, the author only estimates the last part of the CDM model, i.e. relationship between innovation output and productivity. Selection problem from only using the last part of the model will be solved with Heckman selection model, which will be discussed in more detail in the later part of this chapter. The author regresses all of the four possible activity combinations of the two activities with other independent variables, where dependent variable is firm's performance indicator.

To econometrically test for complementarity/substitutability the author uses one-sided z-tests to compare the estimated coefficients of activity combinations dummies from the Heckman model. Based on Brynjolfsson and Milgrom (2013) and Milgrom and Roberts (1995), we will provide more detailed and methodological description of supermodularity approach.

We suppose that there are n binary activities and the payoff function is $(x), x \in \{0,1\}^{n}$, where 0 denotes not taking part in the activity and 1 denotes taking part in the activity. Firm can take part in any number of activities or none of the activities. The function of binary activities $f\ (x_i, x_j, x_{-ij})$ is supermodular and two action j and i are (weakly) complements only if:

$$(1)\ f\left(1,1,x_{-ij}\right) - f\left(0,0,x_{-ij}\right) \geq \left(f\left(1,0,x_{-ij}\right) - f\left(0,0,x_{-ij}\right)\right) + \left(f\left(0,1,x_{-ij}\right) - f\left(0,0,x_{-ij}\right)\right)$$

i.e. taking part in activity while already performing the other activity has a higher incremental effect on performance function f than, the sum of the effect of performing these activities separately.

For (weakly) substitutability opposite needs to be true:

$$(2)\ f\left(1,1,x_{-ij}\right) - f\left(0,0,x_{-ij}\right) \leq \left(f\left(1,0,x_{-ij}\right) - f\left(0,0,x_{-ij}\right)\right) + \left(f\left(0,1,x_{-ij}\right) - f\left(0,0,x_{-ij}\right)\right)$$

i.e. taking part in activity while already performing the other activity has a lower incremental effect on performance function f than, the sum of the effect of performing these activities separately.

For example when we compare two activities then our mathematical model (3) will look like following:

$$(3)\ f(1,1) - f(0,0) \geq (\leq)\ (f(1,0) - f(0,0)) + (f(0,1) - f(0,0))$$

All of the methodology is separately completed for each of the activity pairs. We have product innovation together with marketing innovation, product innovation together with co-operation with clients and marketing innovation together with co-operation with clients.

One of this paper’s core concept is also performance and productivity of the firm. There are many different ways to measure firm’s performance. The author of this paper has decided to use total factor productivity (TFP) as one of the main indicator of the firm’s performance. TFP is a productivity measure, which was first introduced by Solow (1957) and has become more popular in recent times, because we have better access to firm level data that is needed to calculate TFP more precisely. TFP measures how efficiently firm uses its inputs to produce output. To estimate TFP, we first need to decide the production function form. Theoretically assuming that the production function is translog type would give the most precise estimates, because it is more flexible and less restrictive. However, most of the papers, which study TFP use Cobb-Douglas function (Arnold, 2005). Reason for using more restricted Cobb-Douglas function is that it is easier to implement and the results are usually not that different from the translog function. The more detailed theoretical overview and TFP calculation methods are presented in Appendix: Methodology of Total Factor Productivity.

In addition, to compare the results of different type of performance indicators and how they are affected by the different innovation types and their combinations, then the author also includes models, where the performance indicator is turnover per employee, which has been used as a performance indicator in several papers studying the effects of innovations (Roper *et al.*, 2008; Griffith *et al.*, 2006; Ballot *et al.*, 2015). Turnover is used in numerous papers studying effects of innovation activities on the performance of the firm, because CIS only collects performance information for the turnover of the firm

To estimate the effects of firms' innovation activity combinations on the performance of the firm, we use Heckman model. The reason why we use Heckman model is, because our data is divided into those firms that implemented innovation in the analyzed period and to those who tried to innovate, but ended up not implementing the innovation for that period. Selection problem comes from the fact that there might be underlying variables that affect the firm's decision/ability to innovate and if we don't take them into account then traditional OLS, for only the sample of firms that innovated, will be biased and inconsistent. Heckman's (1976) selection model helps us to solve the selectivity problem by estimating the underlying probability of innovating based on chosen variables.

The control variables of selection model and the main model are based mainly on the combination of Ballot *et al.* (2015) and Polder *et al.* (2010) works, which studied the complementary effect of product, process and organizational innovations. Ballot *et al.* (2015) uses turnover per employee as the performance indicator and Polder *et al.* (2010) uses TFP as the performance indicator in their work. However, the author has excluded some of the variables in previously mentioned papers, which are too subjective to the firm (e.g. different obstacles, that are more present only when the firms are more active in those fields) and that are not collected for Estonian firms (e.g. e-purchases and e-sales). In addition the author has added two extra variables: regional location dummy, which is included in Parisi *et al.* (2006) work, and European Union[3] (EU) average innovation activity. Therefore, in this paper the author uses EU average innovation activity by two-digit sector dummies, belonging to a group of firms dummy, exporting dummy, number of employees and North-Estonia location dummy for the selection part of the model. The second step is to estimate the main model while taking into account the selection part of the model. For the main model author uses the studied activity combinations, number of employees, capital intensity, the first period performance indicator, North-Estonia location dummy, innovation dummies that are not used in the activity combinations and exporting dummy. In following paragraphs the author further explains the reasons, why these specific variables are used in the models.

The author chose to control for industry sector level effect by adding EU average innovation activity by two-digit sector dummies to account for the industry specific effect on the probability of the firms being innovative in the selection model. We assume that the EU average innovation activity does not affect the performance measure, but has an effect on the probability of Estonian firms being innovative. Controlling for industry level effect is important, because technology firms have shown to be much more active in innovating than transport and telecommunication firms and the overall differences in innovations are quite large for different industries (Pires *et al.*, 2008; Syverson, 2011).

Export dummy is used in the selection model as indicator of whether the firm has passed the entry barrier to foreign market and in the main model as higher performance indicator. Based on Italian firms Basile (2001) showed that exporting firms tend to innovate more, especially in product innovation. Wagner (2007) found that exporting firms are more productive than the non-exporting firms. However, with exporting there is always a question of causality and

[3] Countries included in the average innovation activity calculations are Bulgaria, Cyprus, Czech Republic, Germany, Estonia, Spain, Croatia, Hungary, Lithuania, Norway, Portugal, Romania, Slovenia and Slovakia.

research with panel data has shown that the relationship between exporting and innovation or performance can be in both directions (Wagner, 2007; Damijan *et al.*, 2010).

Group indicator is used to take into account the spillover effect of group of firms. We assume that if one of those firms in the group innovates then they will also implement that innovation in other similar firms in the group. In addition, group of firms are usually financially more capable and therefore, they have more resources to innovate (Ballot *et al.*, 2015). However, belonging to group of firms can also make innovating more difficult, because enterprises usually have many different systems in place that also need to be changed with innovations, long term growth plans and intrafirm politics, which all make implementing innovation slow and costly (Owens, Fernandez, 2014). Masso and Vahter (2012) found that belonging to enterprise group had negative effect on the implementation of process innovation and insignificant results for product innovation. The variable of belonging to enterprise group has been used by many authors to explain the propensity to innovate in the selection part of the models and also to distinguish selection model set of control variables from the performance equation set of control variables (e.g. Masso and Vahter, 2012; Mohnen and Röller, 2005; Ballot *et al.*, 2015, Polder *et al.*, 2010).

Number of employees variable is taken as the size indicator of the firm for both of the selection and main model. The variable is added to both of the model parts, because size should affect the propensity to innovate and the performance of the firm. Number of employees is used as the firm size indicator in many other works studying innovations effect on the performance of the firm. For example Ballot *et al.*, (2015), Polder *et al.*, (2010), Vahter and Masso (2012) to mention few.

Capital intensity is measured with logarithmic capital and labour ratio. This variable is added to the main model to control the capital intensity effect in the performance measures. Research has also shown that more capital intensive firms have higher performance than low capital intensive firms, especially in manufacturing industry (Datta *et al.*, 2005; Mahesha, 2008). Lööf and Heshmati (2002) found that labour-intensive and capital-intensive firms do not have different levels of propensity to innovate. The differences between industries are also already covered by EU average innovation activity by sector in the selection model. Therefore, capital intensity is only included in the main part of the Heckman selection model. Capital intensity has been included as control variable for performance estimation models in previously mentioned works from Polder *et al.* (2010) and Parisi *et al.* (2006).

The North-Estonia location dummy is also added to both of the selection and the main model. The author assumes that the capital of Estonia and areas near it have higher probability of innovating and having higher performance. The assumption comes from the fact that North-Estonia has over 57% of the whole Estonian active workforce with much higher salary than the average of all other counties (27% higher) (Statistics Estonia Database, 2017). From that we can assume that North-Estonia has most of the skilled workforce, because they have most of the workers and also highest average salary. Therefore, firms can also experience spillover effect and communication advantages from having most of the firms in one region. Already from the descriptive statistics from Table 1, we see that over half of the firms in the sample are registered in North-Estonia and as a matter of fact, in service industry 76% of firms that implemented innovation are registered in North-Estonia. However, we need to take into account the fact that we use firms registry address as the dummy and that firms can have businesses in other parts of the country.

To control for the effects of other innovation types the author added innovation dummies that are not the focus of this paper to the main model to control their effect on the performance of the firm. For all of the models there are process innovation and organizational innovation dummy. Since we study the effects of innovation activity combinations as pairs, then there is also the one missing action dummy, which is not included in the main pairwise analysis. For example if we study the effects of product innovation and co-operation dummy combinations then we add marketing innovation dummy as the control variable.

From the empirical part, we can see from the likelihood-ratio test indicator $\sqrt{\rho}$ (athrho), that there exists selection problem when we use TFP as the dependent variable, but selection problem does not exist when we use turnover per employee as the dependent variable.

However, to have comparable models we will still use Heckman model for the turnover per employee, since the effect on the coefficients is marginally small.

The data also might have unobserved heterogeneity between studied actions. For example if two actions x and y are complements to each other and the firms are aware of that or assume it, then variable z, which directly increases the probability of implementing action x or y, will also indirectly increase the probability of implementing the other action (if z increases the probability of implementing x (or y) then it will also indirectly increase the probability of implementing y (or x)). Therefore, complementarity effect can create a clustering of action x and y, even if we control for different exogenous characteristics for observable variables. Arora and Gambardella (1990) wrote one of the first papers to formulize mathematically the idea of complementary clustering and also showed that it holds empirically in large biotech firms between complementary external linkages.

To give more information about the clustering of product and marketing innovation and co-operation with clients, the author will use previously mentioned complementarities in use approach to provide supporting and informational results for the main part of the empirical analysis.

5. Regression and supermodularity test results

In Appendix 2, 3 and 4, we see the unconditional effects of different combinations of product innovation, marketing innovation and co-operation with clients for the whole sample. In Appendix 2, we present the mean of TFP and turnover per employee for product and marketing innovation combinations. From there, we see that the group with no product innovation and no marketing innovation has the lowest TFP. The unconditional effects of marketing and product innovation are positive on the mean TFP and when we have both, product and marketing innovation, then the mean TFP is the highest. Same results are for the mean of the turnover per employee measure. In Appendix 3, we have unconditional effects of product innovation and co-operation with clients on the performance indicators. In this case again the group with no product innovation and no co-operation with clients has the lowest mean TFP and turnover per employee. However, the highest mean performance measure is for group that co-operates with clients and has not adopted product innovation. It might be the result of having quite small sample size for firms that have co-operated with clients and have not implemented any product innovation. The unconditional effects of marketing innovation and co-operation with clients are presented in Appendix 4. Similarly to previous results, group with no co-operation with clients and no marketing innovation has the lowest mean performance measures. Co-operation with clients and marketing innovation separately have higher performance measures, but the highest performance measures are for group, which have implemented marketing innovation and are also co-operating with clients. We will now continue with regression results to get a better idea how product, marketing innovation and co-operation with clients affect the performance measures together with other control variables.

The results of complete regression models are presented in Appendix 6 for the manufacturing industry and in Appendix 7 for the service industry. Here the author brings out only the main part of the model to keep the main empirical result section fairly concise. The results for manufacturing and service firms are presented together in one table per the action pair.

Table 2. Correlation between product innovation, marketing innovation and co-operation with clients

	Product innovation	Marketing innovation	Co-operation with clients
Product innovation	1	-	-
Marketing innovation	0.3911***	1	-
Co-operation with clients	0.3908***	0.2381***	1

Notes. * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: CIS and Estonian Business Register, calculations by the author

In Table 2, we have the correlation results between the studied actions. From these results, we see that product innovation has low level moderate positive correlation with marketing innovation and co-operation with clients and that for marketing innovation and co-operation with clients we have weak correlation. Therefore, we do not have any major clusters in our data and none of the strategies is dominant. However, from the descriptive statistics part we know that the smallest sized action in our sample is the co-operation with clients, where about 20% of the whole sample has implemented co-operation with clients and from the product innovation and co-operation combinations from Appendix 3, we also see that combination of only implementing co-operation with clients is underrepresented in our sample.

For selection part (see Appendix 6 and 7), we will concentrate on the results of models, where TFP is the dependent variable, because the selection part for turnover per employee is not statistically significant [4]. With selection part of the model we try to explain why some firms did not innovate in the studied period. We see that the EU average innovation activity by sectors variables are always statistically significant for service industry and for manufacturing industry. The size of the firm variable, as natural logarithm from number of employees, is statistically significant for the model with dependent variable as TFP and it is with negative sign for both of the industries. This result has been also noted before by Acs and Audretsch (1987) in relatively innovative industries, where the flexibility of smaller firms gives an advantage in implementing innovations. One explanation can also be the governmental regulations and investment climate, which supports smaller firms to innovate and has created quite a lot of successful start-up hubs to Estonia (Startup Estonia, 2017). The belonging to a group of firms indicator is strongly statistically significant for service industry, but weakly statistically significant for manufacturing industry and only when studying the product innovation and co-operation with clients combinations. The coefficient is with a negative sign for both of the industries. Belonging to group can hinder innovation by having bureaucratic and legacy systems that make the innovation process slow and expensive (Owens and Fernandez, 2014). For manufacturing industry export dummy is statistically insignificant, but for service industry it is statistically significant. Exporting coefficient is with a positive sign for the service industry, but because of causality problem and because we study all of the observations in same time dimension, we can’t state for a fact that exporting increases the probability of innovating and that innovating does not affect exporting positively, although Basile (2001) showed with panel data that exporting firms have higher probability to also innovate. North-Estonia dummy is only statistically

[4] Henceforth statistically significant will mean at least $\alpha = 0.1$ or smaller.

significant for manufacturing industry and shows positive effect on propensity to innovate. This supports the previous statements made in the data description part about spillover effect and the positive effect of having most of the skilled workforce in one place.

Before going through the results of studied action combination effects on the performance of the firm, we will give a brief overview of the estimates of other control variables in the main part of the models. Size of the firm is statistically significant for turnover per employee in both industries and for TFP only in manufacturing industry. The effect of size on the turnover per employee is negative and for TFP positive. Polder *et al.* (2010) found that the effect of size has different results in both industries and can have positive effect on the productivity of manufacturing firms, but opposite for service industry.

Capital intensity is statistically significant and positive for all of the performance indicators in manufacturing industry. This result matches the works of Datta *et al.* (2005), Mahesha (2008) and Polder *et al.* (2010). However, for service industry capital intensity is only statistically significant for turnover per employee.

North-Estonia dummy is statistically significant and has positive effect on the TFP measure for service industry. For manufacturing industry North-Estonia indicator is not statistically significant in any case. Manufacturing firms are less dependent on the location, because they are producing physical goods and most likely without special order or demand from the specific customer. Therefore, it is easier to mass produce the product in other regions than the main economic region. However, service industry acts on the orders of the customer and is more customer specific. In addition, service industry is more skilled labour-intensive and as mentioned before that most of the skilled workforce resides in North-Estonia (Liao *et al.*, 2007; Statistics Estonia Database, 2017). Koh and Riedel (2014) found that service firms are more dependent on the location than the manufacturing firms. These might be the reasons why most of our (76%) innovative service industry firms are gathered in North-Estonia. However, with so high percentage of innovative service firms clustered in North-Estonia, we can't say whether the firm has higher productivity, because of being registered in North-Estonia or firms that have higher productivity have clustered in North-Estonia.

Organizational innovation is statistically significant for all industries and for both performance measures. The positive effect of organizational innovation on the TFP was also found by Polder *et al.* (2010) and for the turnover per employee by Ballot *et al.* (2015).

The process innovation is statistically insignificant for manufacturing industry performance indicator TFP. Cassiman *et al.* (2010) and Crespi *et al.* (2007) also did not find process innovation to be statistically significant for productivity in the case of manufacturing firms. They suggested that, since the process innovation is a change of organizational process and combination of capital investments then we already control for capital in the TFP calculation and we should not expect a statistically significant effect on the TFP measure from process innovation. Furthermore, it explains why process innovation has positive and statistically significant effect on the turnover per employee, because in that case we have not included capital in the calculation of the performance indicator. However, in service industry process innovation has statistically significant negative effect on the TFP measure and it is statistically insignificant with turnover per employee as the performance indicator. The negative effect can be explained with results from the work of Polder *et al.* (2010), where they found that in service industry process innovation together with product innovation has negative effect on the TFP measure. So the statistically negative effect on the TFP measure can come from the concurrence of product and process innovation. Also, there can be initial loss of productivity with implementing new process with workers getting used to the new process and learning to use it (Bourke and Roper, 2016).

Lastly we have export dummy, which is statistically significant and has positive effect on both performance measurements in service industry and only on TFP in manufacturing industry. Exporting has been found to have significant positive effect with productivity in several works and several papers have also shown that the effect is in both directions with exporting firms attaining higher productivity and more productive firms starting to export more (Wagner, 2007; Damijan *et al.*, 2010). Additionally, Masso and Vahter (2012) found that for Estonian firms export has positive relationship with TFP and sales per employee in service industry.

Table 3. Product and marketing innovation combinations: performance function estimation results

	Manufacturing	Manufacturing	Service	Service
	TFP	Turnover per employee	TFP	Turnover per employee
Main model				
Only Marketing Innovation	-0.037	0.042	-0.021	0.059
	(0.027)	(0.039)	(0.044)	(0.047)
Only Product Innovation	0.045	0.150***	0.056	0.136***
	(0.028)	(0.034)	(0.044)	(0.052)
Product and Marketing Innovation	-0.029	0.098***	0.142***	0.126**
	(0.029)	(0.033)	(0.049)	(0.052)
First period TFP	0.868***		0.911***	
	(0.012)		(0.013)	
First period turnover per employee		0.870***		0.839***
		(0.033)		(0.023)
Size	0.031**	-0.079***	-0.021	-0.040**
	(0.013)	(0.014)	(0.015)	(0.018)
Capital Intensity	0.025***	0.068***	-0.010	0.040***
	(0.006)	(0.018)	(0.009)	(0.011)
North Estonia	-0.005	0.018	0.074**	0.014
	(0.021)	(0.025)	(0.036)	(0.040)
Organizational Innovation	0.071***	0.208***	0.064*	0.123***
	(0.021)	(0.028)	(0.034)	(0.037)
Co-operation with clients	-0.024	-0.076**	-0.036	0.009
	(0.033)	(0.037)	(0.047)	(0.050)
Process Innovation	0.009	0.102***	-0.087**	0.011
	(0.020)	(0.027)	(0.036)	(0.038)
Export	0.052*	-0.004	0.069**	0.099**
	(0.026)	(0.037)	(0.031)	(0.041)
Observations	3740	3751	1970	1980
Log Likelihood	-3631.6	-4200.8	-2112.4	-2386.2
Chi-squared	6793.0	4647.7	9432.8	2254.3

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied action combinations is no product innovation and no marketing innovation. Selection model variables together with constant variable are omitted from this table. Full models are presented in Appendix 6 and 7.

Source: CIS and Estonian Business Register, calculations by the author

The author uses one sided z-test based on the supermodularity approach to study the complementarity or substitutability effects between action pairs. We first start with presenting the results of product innovation and marketing innovation combinations. The results for manufacturing and service firms are presented in Table 3. When we take the productivity indicator as TFP for the manufacturing industry, then none of the combination of marketing innovation and product innovation is statistically significantly different from the base category of implementing none of the two studied innovations. However, with turnover per employee as the performance indicator, we see that only implementing product innovation and implementing both product innovation and marketing innovation together have statistically significant positive effect on the turnover per employee measure. From this we can conclude that for manufacturing firms, product innovation and marketing innovation together have higher effect on the turnover per employee than on the measure of the unexplained productivity from the production function. The effect of product innovation and both, marketing and product innovation, being present in turnover per employee indicator and not present in TFP indicator, might be explained by theory of Brynjolfsson and Hitt (2000), which stated that two complementary activities can increase other aspects of the firm that are not present in the productivity measurement, but still positively affect the firm.

For service industry marketing and product innovation together is the only statistically significant combination for TFP and it has positive effect. This suggest complementary effect between product and marketing innovation for the service industry. For turnover per employee, we have statistically significant positive results for only product innovation and also for both of the product and marketing innovation together.

Regression results in Table 4 are for product innovation and co-operation with clients combinations. In the case of manufacturing firm, none of the combinations have any statistically significant effect compared to the base category of no product innovation and co-operation with clients. This goes together with previous combination regression results of product and marketing innovation. With service industry we find that only product innovation and no co-operation with clients has statistically significant positive effect on the TFP. Therefore, together with the results of service industry, we can say that co-operation with clients does not statistically affect the TFP measure. In comparison with turnover per employee, we have that all of the combinations are statistically different from the base category with an exception of only co-operation with clients being not statistically significant for service industry. Only co-operation with clients and no product innovation yields negative effect on the turnover per employee estimation. This is logical, because co-operation with clients has its costs and if it is not used to produce or improve any product innovation, then the result could be negative to the turnover. Only implementing product innovation has positive effect and it goes in line with the previous result of product and marketing innovation combinations. Also product innovation and co-operation with clients together are statistically significantly more positive on the turnover than implementing none of these two actions.

Table 4. Product innovation and co-operation with clients combinations: performance function estimation results

	Manufacturing	Manufacturing	Service	Service
	TFP	Turnover per employee	TFP	Turnover per employee
Main model				
Only Co-operation with clients	-0.016	-0.195*	-0.028	-0.023
	(0.069)	(0.115)	(0.092)	(0.100)
Only Product Innovation	0.034	0.102***	0.091**	0.107**
	(0.023)	(0.028)	(0.040)	(0.046)
Product Innovation and Co-operation	0.007	0.058*	0.060	0.121**
	(0.034)	(0.035)	(0.049)	(0.049)
First period TFP	0.868***		0.910***	
	(0.013)		(0.013)	
First period turnover per employee		0.870***		0.839***
		(0.033)		(0.023)
Size	0.031***	-0.080***	-0.021	-0.041**
	(0.012)	(0.014)	(0.015)	(0.018)
Capital Intensity	0.025***	0.069***	-0.009	0.040***
	(0.007)	(0.018)	(0.009)	(0.011)
North Estonia	-0.004	0.019	0.074**	0.015
	(0.020)	(0.025)	(0.036)	(0.040)
Organizational Innovation	0.071***	0.210***	0.062*	0.124***
	(0.022)	(0.028)	(0.034)	(0.037)
Marketing Innovation	-0.055**	-0.006	0.026	0.029
	(0.022)	(0.026)	(0.034)	(0.036)
Process Innovation	0.010	0.110***	-0.087**	0.014
	(0.020)	(0.026)	(0.037)	(0.039)
Export	0.053**	-0.005	0.068**	0.101**
	(0.027)	(0.037)	(0.031)	(0.041)
Observations	3740	3751	1970	1980
Log Likelihood	-3631.9	-4200.8	-2113.5	-2386.5
Chi-squared	6213.1	4645.1	9607.7	2260.4

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied action combinations is no product innovation and no co-operation with clients. Selection model variables together with constant variable are omitted from this table. Full models are presented in Appendix 6 and 7.

Source: CIS and Estonian Business Register, calculations by the author

Table 5. Marketing innovation and co-operation with clients combinations: performance function estimation results

	Manufacturing TFP	Manufacturing Turnover per employee	Service TFP	Service Turnover per employee
Main model				
Only Co-operation with clients	-0.010	-0.049	-0.057	0.059
	(0.049)	(0.060)	(0.067)	(0.061)
Only Marketing Innovation	-0.050**	0.005	0.017	0.047
	(0.024)	(0.030)	(0.038)	(0.040)
Marketing Innovation and Co-operation	-0.090**	-0.102***	0.011	0.005
	(0.040)	(0.039)	(0.064)	(0.066)
First period TFP	0.868***		0.911***	
	(0.012)		(0.013)	
First period turnover per employee		0.870***		0.838***
		(0.033)		(0.023)
Size	0.031**	-0.080***	-0.021	-0.040**
	(0.013)	(0.014)	(0.015)	(0.018)
Capital Intensity	0.025***	0.069***	-0.009	0.040***
	(0.006)	(0.018)	(0.009)	(0.011)
North Estonia	-0.004	0.019	0.074**	0.014
	(0.021)	(0.025)	(0.036)	(0.040)
Organizational Innovation	0.071***	0.208***	0.063*	0.124***
	(0.021)	(0.028)	(0.034)	(0.037)
Product Innovation	0.032	0.117***	0.092**	0.110***
	(0.022)	(0.028)	(0.036)	(0.042)
Process Innovation	0.010	0.104***	-0.086**	0.010
	(0.020)	(0.027)	(0.036)	(0.038)
Export	0.053**	-0.003	0.068**	0.101**
	(0.026)	(0.037)	(0.031)	(0.041)
Observations	3740	3751	1970	1980
Log Likelihood	-3631.8	-4202.1	-2113.3	-2386.1
Chi-squared	6817.5	4594.5	9487.5	2254.8

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied action combinations is no marketing innovation and no co-operation with clients. Selection model variables together with constant variable are omitted from this table. Full models are presented in Appendix 6 and 7.

Source: CIS and Estonian Business Register, calculations by the author

Last regression results in Table 5 are for marketing innovation and co-operation with clients combinations. Marketing innovation and co-operation with clients together are statistically significant and have negative effects on both of the performance indicators in manufacturing industry. Other research has contrary results that co-operation with clients and marketing innovation tend to correlate with higher performance, although they also mention that the results are varying and do not have as strong and clear effect has expected (Chesbrough, 2006; Cassiman and Veugelers, 2006; Tether 2002). In addition, only implementing marketing innovation is statistically significant and negative for TFP compared to the base category of no marketing innovation and co-operation being implemented. The cause for the negative effect can be from the learning-by-using effect of innovations and co-operation, that was studied by Bourke and Roper (2016) in regards to technological innovations. Innovations have high costs and can have negative effect on the performance of the firm in the first periods of implementation and after time will yield positive effect, when the firm is more accustomed to the innovation. For service industry none of the studied combination show statistically significant difference from the base category of not implementing any of the current innovation actions.

In Table 6, we have complementarity test with supermodularity approach results by industry and action pair. First, we have the results of product and marketing innovation effect. TFP measure gives us inconclusive results. Thus, we can't tell, whether the two innovations have complementary or substitutability effect on each other, when we study their effect on the TFP. However, in the case of turnover per employee, we have substitutability effect between product and marketing innovation. This means that with measuring the performance of a firm with turnover per employee, then product and marketing innovations together have lower effect on the performance indicator than the sum of marketing innovation and product innovation effect separately. The reason for substitutability effect might be that we are studying the firms of quite small country and the strain of implementing two mayor innovation types in three years can be too demanding for firms in small country and therefore, the performance measures are higher if only one innovation is implemented at that time. We can also say that the TFP and the turnover per employee measures evaluate different aspects of the firms and the substitutability effect is due to the fact that turnover evaluates the sales amount of the firms and if a firm innovates new product, then it might not need to implement marketing innovation to sell that product. Since, we already have an innovative product, which might be a new selling point by on its own, then additional marketing innovation does not have as big effect on the sales has it has when no product innovation is present.

Table 6. Results of complementarity test for each action pair and industry

Industry	Action pairs	TFP	Turnover per employee
Manufacture	Product and Marketing Innovation	Inconclusive	Substitutability**
Service	Product and Marketing Innovation	Complementarity*	Inconclusive
Manufacture	Product Innovation and Co-operation	Inconclusive	Complementarity*
Service	Product Innovation and Co-operation	Inconclusive	Inconclusive
Manufacture	Marketing Innovation and Co-operation	Inconclusive	Inconclusive
Service	Marketing Innovation and Co-operation	Inconclusive	Substitutability*

Notes. * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: CIS and Estonian Business Register, calculations by the author

For the service industry firms, we get an opposite result for the complementarity test between product innovation and marketing innovation. Although, turnover per employee shows inconclusive results, then TFP shows that marketing innovation and product innovation have complementary effect on each other. This result is in line with the Junge *et al.* (2016) findings. The contradiction between the work of Junge *et al.* (2016) and the results from the manufacturing industry might come from the fact that Junge *et al.* (2016) do not separate in their sample between service and manufacturing industry observations and the complementary effect in service industry might be dominating the effect of the manufacturing industry.

For product innovation and co-operation with clients in manufacturing industry, we again have inconclusive results for the TFP measure, but complementary effect between two actions in the case of the turnover per employee measure. This result matches Jaworski and Kohli (1993) work. However, we need to take into account that quite small part of our sample includes observations, where firms have co-operated with clients. Tether (2002) also noted that the level of co-operation with clients is fairly low for firms and that there is correlation between co-operation and higher level and more developed innovations. Low levels of formal co-operation with clients create uneven samples for product innovation and co-operation with clients combination samples. With turnover per employee we have 131 observations that have implemented only co-operation with clients and 608 observations have product innovation together with co-operation with clients (with TFP 75 and 373 observations respectively) for both manufacturing and service industry. Thus, previous statement together with the fact that we have much smaller sample for service industry than for manufacturing industry might be a reason for why product innovation and co-operation with clients have inconclusive result for all of the service industry performance indicators.

For action pair marketing innovation and co-operation with clients we don't have any conclusive results for manufacturing industry. For service industry we found that marketing innovation and co-operation have substitutability effect, when we measure performance with turnover per employee. This supports the theory of Christensen and Bower (1996) and Tauber (1974) that co-operation with clients can hinder successful marketing innovation and that radical new ideas that are not even thought by the clients can have better effect on the performance of the firm than the ideas from the clients. However, we again need to take into account that the sample size with positive co-operation with clients is quite small and can have skewed results.

The author assumes that the different results between industries can come from the fact that we have uneven sample of service and manufacturing industry observations and they might have underlying differences from the country based population. In our whole sample, we have almost twice as much of manufacturing industry observations than service industry observations. However, the whole Estonian firm population has only about 9% of manufacturing firms and about 50% of service firms (Statistical Yearbook…, 2016). The descriptive statistics part indicated that in service industry the average performance indicator is higher than in manufacturing industry. Therefore, our service industry sample based on CIS answers may not be random and might have high concentration of firms that are doing very well compared to others in that same industry and might be fit to implement two mayor innovation activities and benefit from them. Whereas for manufacturing firms, we have observations with wider performance range and therefore implementing two major innovation activities might be too straining for the lower performing firms and therefore, show different effects between the innovation activities. This assumption is also supported by the fact that the population average turnover per employee for manufacturing industry is larger than it is for the service industry (Statistical Yearbook…, 2016).

For the robustness tests, the author constructed panel data from the cross-sectional data and pooled together the data for manufacturing industry and service industry. Heckman random effects model produced inconclusive results for complementarity test with all of the innovation action combinations. However, when using OLS fixed effects model to analyze the data, we saw results that support the substitutability relationship between product and marketing innovation and suggest that co-operation with clients and innovations are complementary for productivity, when studying the innovations effect through time. More detailed results for robustness tests can be found from the Appendix: Robustness tests.

6. Conclusions and Discussion

This paper studies the complementary effects of marketing innovation, product innovation and co-operation with clients on the performance of the firm. We analyze the effects separately for manufacturing firms and service firms and also study the complementary effect between the two types of performance measures, TFP and turnover per employee. Other similar papers have usually only included productivity or turnover based measure to study the complementary effect between innovation activities (e.g. Ballot *et al.,* 2015; Polder *et al.,* 2010; Parisi *et al.,* 2006; Junge *et al.,* 2016). Analysis in this paper gives a comparison effect between two types of performance indicators and more information about what exactly different studied actions affect together and how it diverges between industries.

We find that there is no universal complementarity or substitutability between product innovation, marketing innovation and co-operation with clients. The complementary effects between innovation activities differ across performance measures, industries and time dimension.

Our results show that in manufacturing industry product innovation and marketing innovation have substitutability effect. This might be due to the fact that innovative products act also as marketing aspect and do not need any new marketing innovations in place to have higher sales amount. Marketing and product innovation with TFP measure yield inconclusive results for manufacturing firms. However, for service industry we found complementary effect between product and marketing innovations on the TFP measure. Complementary relationship between product innovation and marketing innovation in service industry was only conclusive for the TFP indicator. This indicates that service firms, which implement product and marketing innovation together in a three year period, experience higher productivity. Manufacturing firms, which implement each of these innovations separately have higher positive effect on the performance of the firm than implementing product and marketing innovations together.

Co-operation with clients has complementary effect with product innovation on the turnover per employee performance indicator in manufacturing industry. There are no conclusive effects between product innovation and co-operation with clients in service industry. Co-operation with clients and marketing innovation have together substitutability effect on the turnover per employee measure in service industry. We were expecting co-operation with clients to enhance the effect of marketing innovation, but in the case of service industry it has an opposite effect on the performance of the firm and manufacturing industry has inconclusive result. However, this result supports theories of Christensen and Bower (1996) and Tauber (1974), that co-operation can lead to less successful innovations and additionally it can be explained by curvilinear effect of openness on the performance of the firm that was found by Laursen and Salter (2006).

We assume that the different result between industries might come from the fact that we have very limited sample of service firms in our study compared to the manufacturing industry and as a result the sample of service and manufacturing industry can have underlying differences between the average performance and effect of innovation activities on the firms that does not represent the whole population.

With robustness test, we add panel data aspect to the model. We pool manufacturing and service industry data to get a viable dataset. The results support cross-sectional findings with turnover per employee as the performance indicator and add additional information for the TFP indicator. With TFP as the performance indicator, we see complementary relationship between the co-operation with clients and innovations with panel data. Cross-sectional data analysis showed inconclusive results for TFP for those two action pairs. Therefore, co-operation with clients and product innovation and also co-operation with clients and marketing innovation needs to be studied with time dimensions to see the complementary effect on the firm productivity measure.

It must be mentioned that we have several issues with our data that might affect the results we have and hence, not all of the findings apply to all firms. Firstly, there is a problem of having cross-sectional data in the main empirical part. As a result, we don't observe firms exits and entries from the market and we can't also study the longer term effects of innovations and co-operation separately for each industry. Secondly, we can't be sure that studied actions affect the performance of the firm and that firm performance does not affect implementing and benefiting from the innovation. Thirdly, in the case of studying effects of product innovation and co-operation with clients, we encounter the underrepresentation of observations, where we only have co-operation with clients and no product innovation. Finally, with literature review part we found that works about complementarity effect between innovations and similar action have quite varying result and papers with slightly different model get diverse results, when studying the effects of the same actions. Meaning that the results found in this paper should not be taken as the whole truth, but one aspect of the subject matter.

Further research should include a CDM model to study the effects of product and marketing innovation and co-operation with clients. This would give more insight to the sensitivity of the models used in this paper and show if the results hold up with other model specifications. In addition, other co-operation factors could be more thoroughly studied with depth and breadth of the co-operation and also compare the effect of different co-operations on the marketing and product innovation. Furthermore, it would be complementary to this paper to have a case study of several firms through longer time period to analyze the costs of innovations and co-operation, intensity of non-technological innovations and learning-by-using effect of innovations. The results from those case studies would give more precise idea how innovations and co-operation change the firm and through what exactly the complementary effect is achieved.

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APPENDIX

Appendix 1. Summary of papers studying the complementary effect between innovation types and co-operation

Studied actions	Methodology	Results	Country and industry	Period	Author(s)
Product and marketing innovation	Complementarities in performance Performance indicator as real value added	-Product and marketing innovation have complementary on growth of productivity for skill-intensive firms. -Unskilled-intensive firms experience negative growth rate	Denmark No distinction between industries	CIS4 (2002-2004)	Junge, Severgnini and Sørensen (2016)
Product, process and organizational innovation	Complementarities in performance CDM model and supermodularity approach with performance indicator as TFP calculated with Olley Pakes method	-Product and process innovation do not affect the performance without the presence of organizational innovation. -Product and organizational innovation are substitutes. -Process and organizational innovation are complementary	Netherlands Separate for manufacturing and service industry	Pooled data for CIS3, CIS4 and CIS2006 (1998-2006)	Polder, Leeuwen, Mohnen and Raymond (2010)
Product, process and organizational innovation	Complementarities in performance Performance indicator as sales per employee. Supermodularity approach	-Complementarity between product and process innovation (France and UK) -Complementarity between organizational and product innovation (France)	France and UK Manufacturing firms	CIS4 (2002-2004)	Ballot, Fakhfakh, Galia and Salter (2010)

Product and process innovation	Complementarities in performance CDM model framework with performance indicator as TFP	-Complementarity between product and process innovation	Estonia Service industry	CIS3 CIS4 CIS2006 (1998-2006)	Masso and Vahter (2012)
Internal R&D and external knowledge acquisition	Complementarities in use Performance indicator as number of new or improved products	- Internal R&D and external knowledge acquisition are substitutes	UK Manufacturing industry	Product Development Survey (PDS) 1995	Love and Roper (1999)
Internal R&D and R&D co-operation	Complementarities in use and complementarities in performance approach Performance indicator as % sales from new products	-Complementary effect between internal R&D and co-operation	German Manufacturing industry	CIS 3 (1998-2000)	Schmiedeberg (2008)
Internal R&D and external knowledge acquisition	Complementarities in use and complementarities in performance approach Performance indicator as % sales from new products	-Complementary effect between internal R&D and external knowledge acquisition, however the complementary effect is very sensitive and other firm strategic decisions affect the results heavily	Belgium Manufacturing industry	CIS 1993	Cassiman and Veugelers (2006)

Source: Compiled by the author based on the citations in the table

Appendix: Descriptive Statistics

Appendix 2. Product and marketing innovation combinations: descriptive statistics about TFP and turnover per employee

Performance measure	**Variable**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
TFP	No Product and Marketing Innovation	2,363	9.305	1.108	5.842	12.138
TFP	Only Marketing Innovation	403	9.497	1.125	5.995	11.987
TFP	Only Product Innovation	606	9.504	1.026	5.667	12.090
TFP	Both Innovations	641	9.601	1.068	6.345	12.014
Turnover per employee	No Product and Marketing Innovation	3,491	10.660	1.194	2.212	19.101
Turnover per employee	Only Marketing Innovation	643	10.999	1.115	6.860	15.363
Turnover per employee	Only Product Innovation	953	10.930	1.029	5.461	14.408
Turnover per employee	Both Innovations	1,061	11.084	1.0335	5.999	14.901

Notes. Both variables are in logarithmic form.

Source: CIS and Estonian Business Register, calculations by the author

Appendix 3. Product innovation and co-operation with clients combinations: descriptive statistics about TFP and turnover per employee

Performance measure	**Variable**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
TFP	No Product Innovation and Co-operation with Clients	2,691	9.313	1.109	5.842	12.138
TFP	Only Co-operation with Clients	75	10.050	1.026	7.174	12.007
TFP	Only Product Innovation	874	9.527	1.055	-5.667	12.085
TFP	Both Innovation Activities	373	9.617	1.032	6.326	11.992
Turnover per employee	No Product Innovation and Co-operation with Clients	4,003	10.699	1.183	2.212	19.101
Turnover per employee	Only Co-operation with Clients	131	11.124	1.255	5.945	15.363
Turnover per employee	Only Product Innovation	1,406	10.977	1.049	5.461	14.832
Turnover per employee	Both Innovation Activities	608	11.091	.995	7.952	14.901

Notes. Both variables are in logarithmic form.

Source: CIS and Estonian Business Register, calculations by the author

Appendix 4. Marketing innovation and co-operation with clients combinations: descriptive statistics about TFP and turnover per employee

Performance measure	Variable	Obs	Mean	Std. Dev.	Min	Max
TFP	No Marketing Innovation and Co-operation with Clients	2,769	9.321	1.094	5.667	12.138
TFP	Only Co-operation with Clients	200	9.678	1.059	6.326	12.007
TFP	Only Marketing Innovation	796	9.518	1.106	5.995	12.014
TFP	Both Innovation Activities	248	9.698	1.031	6.980	11.987
Turnover per employee	No Marketing Innovation and Co-operation with Clients	4,120	10.692	1.1676	2.212	19.101
Turnover per employee	Only Co-operation with Clients	324	11.040	1.090	5.945	14.408
Turnover per employee	Only Marketing Innovation	1,289	11.023	1.082	5.999	14.832
Turnover per employee	Both Innovation Activities	415	11.141	1.007	8.108	15.363

Notes. Both variables are in logarithmic form.

Source: CIS and Estonian Business Register, calculations by the author

Appendix: Methodology of Total Factor Productivity

In this paper, the author uses total factor productivity (TFP) and turnover per employee as the performance indicators for the firms. Most of firm level productivity studies take output as a function of the inputs (goods, raw material, services etc.) and the productivity of the firm (Katayama *et al.*, 2009). The measure of TFP is in reality the residuals of the function. There are several possible ways to calculate those residuals and they all have their pros and cons. Appendix 5 provides short review of the pros and cons of the most popular TFP estimation methods.

Appendix 5. Pros and cons of different TFP estimation methods

TFP Estimation Method	Pros	Cons
1. Ordinary least squares (OLS)	-easy to implement -has been used in many papers and makes the results comparable	-simultaneity and endogeneity problem from correlated input and productivity -selection bias from entry and exit -missing proxy variable
2. Fixed Effects	-more consistent coefficients than OLS method -eliminates the selection bias	-unreasonably low estimations of capital in practice -underlying assumptions usually don’t hold

3. Instrumental Variables (IV) and GMM	-more consistent coefficients than OLS method -strict exogeneity of the inputs does not need to be true	-relies on input prices that are usually not reported/usable -correlation between instrument and productivity, because wages tend to be varying by skill and quality of the workers -assumes that productivity develops exogenously over time
4. Olley-Pakes (OP)	-consistent semi-parametric estimator -solves the simultaneity problem with investments proxy variable -allows for shocks	-investments need to be strictly increasing in productivity/only positive investments are used for estimation -less usable observations, because of the monotonicity requirement -assumes that there is at least one input that is affected by new information instantly and is costless to change -labour coefficient can be collinear in first-stage estimation and not identified (smaller effect on the estimator)
5. Levinsohn-Petrin (LP)	-consistent semi-parametric estimator -solves the simultaneity problem with materials/energy proxy variable -more observations due to intermediate inputs as proxy -allows for shocks	-assumes that there is at least one input that is affected by new information instantly and is costless to change -labour coefficient can be collinear in first-stage estimation and not identified (larger effect on the estimator)
6. Ackerberg-Caves-Frazer (ACF)	-extended version of OP method -solves the multi-collinearity and identification of labour variable	-consistency of estimators varies -not always the most efficient estimator
7. Woolridge	-based on OP, LP and ACF -robust standard errors can be calculated without bootstrapping -more efficient than two-step semi-parametric methods -accounts for the identification problem of labour variable	-input demands are strictly restrictive

Sources: Ackerberg *et al.*, 2007; Van Beveren, 2012; Ackerberg *et al.*, 2006; Levinsohn and Petrin, 2003; Olley and Pakes, 1992; Wooldridge, 2009. Compiled by the author.

For this paper, the author uses Levinsohn-Petrin method to calculate the TFP measure for the firms. Levinsohn-Petrin method was chosen, because it solves most of the main problems of calculating TFP and it leaves us more observations to analyze. The last part is very important, due to the fact that we have relatively small dataset and quite many innovation activity dummy combinations and this method provides more data for each of those combinations.

The production function (4) is based on Cobb-Douglas and is mathematically as follows:

$$(4)\ Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta}M_{it}^{\gamma}$$

where Y denotes output, K the capital, L labour, M materials and A the Hicksian neutral efficiency level of firm i for period t. α, β and γ are the shares of variables K, L, M and $\alpha + \beta + \gamma = 1$. Output, capital, labour and materials are observed variables and A is the unobserved variable. We can separate logarithmic A into two parts:

$$(5)\ \ln(A_{it}) = \beta_0 + \varepsilon_{it}$$

where β_0 is the mean efficiency level of all of the used firms over time and ε_{it} is the i firm's deviation from the mean efficiency level in period t. ε_{it} in turn can again be separated into predictable and unobservable component.

For Levinsohn-Petrin method we use pre-programmed STATA program *levpet* that was developed by Petrin *et al.* (2003) with proxy variable as used goods, raw materials, materials, services sum. Since we have data across time then we also deflate all of the variables with GDP deflator. The predicted TFP is the residual of these models.

Appendix: Regression results

Appendix 6. Manufacturing industry performance function estimation results: combinations of product, marketing innovation and co-operation with clients

	Product and Marketing innovation	Product and Marketing innovation	Product innovation and co-operation with clients	Product innovation and co-operation with clients	Marketing innovation and co-operation with clients	Marketing innovation and co-operation with clients
	TFP	Turnover per employee	TFP	Turnover per employee	TFP	Turnover per employee
Main model						
Only Marketing Innovation	-0.037	0.042				
	(0.027)	(0.039)				
Only Product Innovation	0.045	0.150***				
	(0.028)	(0.034)				
Product and Marketing Innovation	-0.029	0.098***				
	(0.029)	(0.033)				
Only Co-operation with clients			-0.016	-0.195*		
			(0.069)	(0.115)		
Only Product Innovation			0.034	0.102***		
			(0.023)	(0.028)		
Product Innovation and Co-operation			0.007	0.058*		
			(0.034)	(0.035)		
Only Co-operation with clients					-0.010	-0.049
					(0.049)	(0.060)
Only Marketing Innovation					-0.050**	0.005
					(0.024)	(0.030)
Marketing Innovation and Co-operation					-0.090**	-0.102***
					(0.040)	(0.039)
First period TFP	0.868***		0.868***		0.868***	
	(0.012)		(0.013)		(0.012)	
First period turnover per employee		0.870***		0.870***		0.870***
		(0.033)		(0.033)		(0.033)

Size	0.031**	-0.079***	0.031***	-0.080***	0.031**	-0.080***
	(0.013)	(0.014)	(0.012)	(0.014)	(0.013)	(0.014)
Capital Intensity	0.025***	0.068***	0.025***	0.069***	0.025***	0.069***
	(0.006)	(0.018)	(0.007)	(0.018)	(0.006)	(0.018)
North Estonia	-0.005	0.018	-0.004	0.019	-0.004	0.019
	(0.021)	(0.025)	(0.020)	(0.025)	(0.021)	(0.025)
Organizational Innovation	0.071***	0.208***	0.071***	0.210***	0.071***	0.208***
	(0.021)	(0.028)	(0.022)	(0.028)	(0.021)	(0.028)
Process Innovation	0.009	0.102***	0.010	0.110***	0.010	0.104***
	(0.020)	(0.027)	(0.020)	(0.026)	(0.020)	(0.027)
Product Innovation					0.032	0.117***
					(0.022)	(0.028)
Marketing Innovation			-0.055**	-0.006		
			(0.022)	(0.026)		
Co-operation with clients	-0.024	-0.076**				
	(0.033)	(0.037)				
Export	0.052*	-0.004	0.053**	-0.005	0.053**	-0.003
	(0.026)	(0.037)	(0.027)	(0.037)	(0.026)	(0.037)
Constant	1.065***	0.964***	1.069***	0.967***	1.068***	0.970***
	(0.114)	(0.246)	(0.118)	(0.247)	(0.113)	(0.247)
Selection model						
EU average innovation activity	0.752***	1.238***	0.750***	1.238***	0.750***	1.240***
	(0.203)	(0.205)	(0.161)	(0.205)	(0.203)	(0.211)
Size	-0.213***	0.010	-0.213***	0.011	-0.213***	0.010
	(0.038)	(0.040)	(0.024)	(0.040)	(0.038)	(0.040)
Group	-0.089	0.085	-0.090*	0.084	-0.090	0.085
	(0.069)	(0.088)	(0.047)	(0.087)	(0.068)	(0.087)
Export	-0.036	0.148	-0.036	0.149	-0.036	0.148
	(0.086)	(0.108)	(0.064)	(0.108)	(0.086)	(0.108)
North Estonia	0.227***	-0.095	0.227***	-0.095	0.227***	-0.095
	(0.070)	(0.072)	(0.043)	(0.072)	(0.070)	(0.072)
Constant	1.338***	1.353***	1.337***	1.353***	1.337***	1.353***
	(0.167)	(0.184)	(0.116)	(0.184)	(0.167)	(0.183)
$\sqrt{\rho}$ Constant	-0.745***	-0.154	-0.746***	-0.149	-0.748***	-0.154
	(0.125)	(0.191)	(0.130)	(0.182)	(0.124)	(0.191)

ln(σ) Constant	-0.755***	-0.464***	-0.754***	-0.464***	-0.754***	-0.464***
	(0.046)	(0.039)	(0.046)	(0.038)	(0.046)	(0.039)
Observations	3740	3751	3740	3751	3740	3751
Log Likelihood	-3631.6	-4200.8	-3631.9	-4200.8	-3631.8	-4202.1
Chi-squared	6793.0	4647.7	6213.1	4645.1	6817.5	4594.5

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied actions combinations is when none of the studied two actions are implemented.

Appendix 7. Service industry performance function estimation results: combinations of product, marketing innovation and co-operation with clients

	Product and Marketing innovation	Product and Marketing innovation	Product innovation and co-operation with clients	Product innovation and co-operation with clients	Marketing innovation and co-operation with clients	Marketing innovation and co-operation with clients
	TFP	Turnover per employee	TFP	Turnover per employee	TFP	Turnover per employee
Main model						
Only Marketing Innovation	-0.021	0.059				
	(0.044)	(0.047)				
Only Product Innovation	0.056	0.136***				
	(0.044)	(0.052)				
Product and Marketing Innovation	0.142***	0.126**				
	(0.049)	(0.052)				
Only Co-operation with clients			-0.028	-0.023		
			(0.092)	(0.100)		
Only Product Innovation			0.091**	0.107**		
			(0.040)	(0.046)		
Product Innovation and Co-operation			0.060	0.121**		
			(0.049)	(0.049)		
Only Co-operation with clients					-0.057	0.059
					(0.067)	(0.061)
Only Marketing Innovation					0.017	0.047
					(0.038)	(0.040)
Marketing Innovation and Co-operation					0.011	0.005

					(0.064)	(0.066)
First period TFP	0.911***		0.910***		0.911***	
	(0.013)		(0.013)		(0.013)	
First period turnover per employee		0.839***		0.839***		0.838***
		(0.023)		(0.023)		(0.023)
Size	-0.021	-0.040**	-0.021	-0.041**	-0.021	-0.040**
	(0.015)	(0.018)	(0.015)	(0.018)	(0.015)	(0.018)
Capital Intensity	-0.010	0.040***	-0.009	0.040***	-0.009	0.040***
	(0.009)	(0.011)	(0.009)	(0.011)	(0.009)	(0.011)
North Estonia	0.074**	0.014	0.074**	0.015	0.074**	0.014
	(0.036)	(0.040)	(0.036)	(0.040)	(0.036)	(0.040)
Organizational Innovation	0.064*	0.123***	0.062*	0.124***	0.063*	0.124***
	(0.034)	(0.037)	(0.034)	(0.037)	(0.034)	(0.037)
Process Innovation	-0.087**	0.011	-0.087**	0.014	-0.086**	0.010
	(0.036)	(0.038)	(0.037)	(0.039)	(0.036)	(0.038)
Product Innovation					0.092**	0.110***
					(0.036)	(0.042)
Marketing Innovation			0.026	0.029		
			(0.034)	(0.036)		
Co-operation with clients	-0.036	0.009				
	(0.047)	(0.050)				
Export	0.069**	0.099**	0.068**	0.101**	0.068**	0.101**
	(0.031)	(0.041)	(0.031)	(0.041)	(0.031)	(0.041)
Constant	0.778***	1.447***	0.773***	1.456***	0.773***	1.456***
	(0.135)	(0.248)	(0.136)	(0.247)	(0.135)	(0.247)
Selection model						
EU average innovation activity	1.058***	1.053***	1.056***	1.058***	1.056***	1.056***
	(0.278)	(0.316)	(0.278)	(0.316)	(0.278)	(0.316)
Size	-0.094**	-0.162***	-0.094**	-0.163***	-0.094**	-0.162***
	(0.046)	(0.045)	(0.046)	(0.045)	(0.046)	(0.045)
Group	-0.347***	0.195*	-0.346***	0.197*	-0.346***	0.196*
	(0.090)	(0.109)	(0.090)	(0.109)	(0.090)	(0.109)
Export	0.317***	0.063	0.317***	0.062	0.317***	0.063
	(0.087)	(0.097)	(0.087)	(0.097)	(0.087)	(0.097)
North Estonia	-0.099	-0.205**	-0.099	-0.205**	-0.099	-0.205**
	(0.100)	(0.103)	(0.100)	(0.102)	(0.100)	(0.102)
Constant	0.986***	1.786***	0.986***	2.357***	0.986***	2.355***
	(0.189)	(0.195)	(0.189)	(0.195)	(0.189)	(0.195)

$\sqrt{\rho}$ Constant	0.260**	-0.128	0.256**	-0.135	0.255**	-0.133
	(0.107)	(0.177)	(0.108)	(0.178)	(0.107)	(0.178)
$\ln(\sigma)$ Constant	-0.705***	-0.483***	-0.705***	-0.336***	-0.705***	-0.483***
	(0.048)	(0.061)	(0.048)	(0.061)	(0.048)	(0.061)
Observations	1970	1980	1970	1980	1970	1980
Log Likelihood	-2112.4	-2386.2	-2113.5	-2386.5	-2113.3	-2386.1
Chi-squared	9432.8	2254.3	9607.7	2260.4	9487.5	2254.8

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied actions combinations is when none of the studied two actions are implemented.

Appendix: Robustness tests

For robustness analysis the author constructed panel data from the previous cross-sectional dataset. To get viable dataset for the analysis, we chose to not separate between manufacturing and service industry for the following tests and we kept firms, which had at least three consecutive CIS results.

We first start with using random effects selection model on panel data. We can’t use Heckman selection model command with panel data. Therefore, we estimate random effects probit model for the selection part of the model and then calculate inverse Mills ratio from those results. The inverse Mills ratio will be added to the main model as control variable to control for selectivity.

The regression results for all of the action combination are presented in Appendix 9. The results don’t differ too much from the cross-sectional data results, however we need to take into account that in the main empirical part we separate between manufacturing industry and service industry.

In Appendix 8, we see complementarity test with supermodularity approach results for complementarities between studied actions. None of the actions pairs give as any conclusive results.

Appendix 8. Selection model with panel data results of complementarity test for each action pair

Action pairs	TFP	Turnover per employee
Product and Marketing Innovation	Inconclusive	Inconclusive
Product Innovation and Co-operation	Inconclusive	Inconclusive
Marketing Innovation and Co-operation	Inconclusive	Inconclusive

Notes. * significant at 10%; ** significant at 5%; *** significant at 1%.

Source: CIS and Estonian Business Register, calculations by the author

Appendix 9. Performance function estimation results with Heckman random effects model: combinations of product, marketing innovation and co-operation with clients with panel data

	Product and Marketing innovation	Product and Marketing innovation	Product innovation and co-operation with clients	Product innovation and co-operation with clients	Marketing innovation and co-operation with clients	Marketing innovation and co-operation with clients
	TFP	Turnover per employee	TFP	Turnover per employee	TFP	Turnover per employee
Only Marketing Innovation	-0.015 (0.030)	0.046 (0.033)				
Only Product Innovation	0.053* (0.028)	0.093*** (0.032)				
Product and Marketing Innovation	0.039 (0.031)	0.088*** (0.031)				
Only Co-operation with clients			-0.060 (0.061)	-0.122 (0.106)		
Only Product Innovation			0.051** (0.024)	0.066** (0.027)		
Product Innovation and Co-operation			0.017 (0.039)	0.028 (0.033)		
Only Co-operation with clients					-0.061 (0.052)	-0.067 (0.052)
Only Marketing Innovation					-0.022 (0.025)	0.018 (0.026)
Marketing Innovation and Co-operation					-0.041 (0.037)	-0.031 (0.040)
Size	-0.040** (0.018)	-0.155*** (0.030)	-0.041** (0.018)	-0.156*** (0.031)	-0.041** (0.018)	-0.156*** (0.030)
Capital Intensity	0.003 (0.007)	0.060*** (0.015)	0.003 (0.007)	0.060*** (0.015)	0.003 (0.007)	0.060*** (0.015)
First period TFP	0.846*** (0.014)		0.846*** (0.015)		0.846*** (0.014)	
First period turnover per employee		0.770*** (0.034)		0.769*** (0.034)		0.770*** (0.034)

North Estonia	0.033	0.031	0.033	0.032	0.033	0.031
	(0.021)	(0.028)	(0.021)	(0.028)	(0.021)	(0.028)
Organizational innovation	0.048**	0.207***	0.048**	0.208***	0.049**	0.208***
	(0.022)	(0.025)	(0.022)	(0.025)	(0.022)	(0.025)
Process Innovation	-0.018	0.039	-0.018	0.042*	-0.017	0.040*
	(0.022)	(0.024)	(0.022)	(0.024)	(0.022)	(0.024)
Product Innovation					0.054**	0.076***
					(0.023)	(0.026)
Marketing Innovation			-0.015	0.021		
			0.022	0.024		
Co-operation with clients	-0.040	-0.057				
	(0.034)	(0.036)				
Export	0.050*	0.057*	0.050*	0.058*	0.050*	0.058*
	(0.027)	(0.033)	(0.028)	(0.033)	(0.028)	(0.033)
Inverse Mills ratio	-0.199**	-0.091	-0.199**	-0.092	-0.199**	-0.093
	(0.086)	(0.116)	(0.086)	(0.117)	(0.086)	(0.116)
Constant	1.618***	2.415***	1.618***	2.431***	1.622***	2.422***
	(0.194)	(0.383)	(0.194)	(0.386)	(0.194)	(0.385)
Observations	2338	3618	2338	3618	2338	3618
Chi-squared	5978.2	2820.1	6064.5	2787.3	5957.7	2843.1

Notes. Standard errors are robust. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied actions combinations is when none of the studied two actions are implemented.

Appendix 10. Performance function estimation results with OLS fixed effects model: combinations of product, marketing innovation and co-operation with clients with panel data

	Product and Marketing innovation	Product and Marketing innovation	Product innovation and co-operation with clients	Product innovation and co-operation with clients	Marketing innovation and co-operation with clients	Marketing innovation and co-operation with clients
	TFP	Turnover per employee	TFP	Turnover per employee	TFP	Turnover per employee
Only Marketing Innovation	-0.016	0.074**				
	(0.029)	(0.029)				
Only Product Innovation	0.069**	0.055**				
	(0.028)	(0.027)				
Product and Marketing Innovation	0.028	0.063**				
	(0.028)	(0.028)				
Only Co-operation with clients			-0.124**	-0.119		
			(0.053)	(0.092)		
Only Product Innovation			0.051**	0.018		
			(0.025)	(0.024)		
Product Innovation and Co-operation			0.030	0.031		
			(0.042)	(0.031)		
Only Co-operation with clients					-0.085	-0.042
					(0.052)	(0.046)
Only Marketing Innovation					-0.043*	0.033
					(0.023)	(0.022)
Marketing Innovation and Co-operation					-0.046	0.043
					(0.040)	(0.036)
Size	0.033	-0.802***	0.033	-0.799***	0.032	-0.800***
	(0.036)	(0.038)	(0.036)	(0.038)	(0.036)	(0.038)
Capital Intensity	0.001	-0.002	0.001	-0.003	0.001	-0.003
	(0.014)	(0.017)	(0.014)	(0.017)	(0.014)	(0.017)
First period TFP	0.186***		0.188***		0.187***	
	(0.038)		(0.038)		(0.038)	
First period turnover per employee		0.079**		0.079**		0.080**

		(0.039)		(0.040)		(0.039)
North Estonia	-0.147	0.021	-0.143	0.026	-0.146	0.019
	(0.142)	(0.060)	(0.141)	(0.058)	(0.141)	(0.058)
Organizational Innovation	0.009	0.088***	0.009	0.089***	0.012	0.090***
	(0.023)	(0.022)	(0.023)	(0.022)	(0.022)	(0.022)
Process Innovation	0.019	0.021	0.021	0.026	0.021	0.023
	(0.021)	(0.020)	(0.021)	(0.020)	(0.021)	(0.020)
Product Innovation					0.063***	0.033
					(0.023)	(0.022)
Marketing Innovation			-0.028	0.042**		
			(0.021)	(0.021)		
Co-operation with clients	-0.043	-0.014				
	(0.035)	(0.033)				
Export	-0.010	0.029	-0.009	0.029	-0.008	0.031
	(0.040)	(0.033)	(0.040)	(0.033)	(0.040)	(0.033)
Constant	7.584***	12.978***	7.580***	12.974***	7.586***	12.970***
	(0.430)	(0.491)	(0.430)	(0.493)	(0.432)	(0.492)
Observations	2551	3977	2551	3977	2551	3977
Log Likelihood	-495.2	-1577.0	-493.9	-1575.9	-493.8	-1578.2
R-squared	0.0445	0.244	0.0455	0.245	0.0455	0.244

Notes. Standard errors are robust. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category of studied actions combinations is when none of the studied two actions are implemented.

To get more thorough idea how the innovations and co-operation with clients complement each other through time, then we use also OLS fixed effects model[5].

Appendix 11. OLS fixed effects model with panel data results of complementarity test for each action pair

Action pairs	TFP	Turnover per employee
Product and Marketing Innovation	Inconclusive	Substitutability**
Product Innovation and Co-operation	Complementarity*	Complementarity*
Marketing Innovation and Co-operation	Complementarity*	Inconclusive

Notes. * significant at 10%; ** significant at 5%; *** significant at 1%.
Source: CIS and Estonian Business Register, calculations by the author

With fixed effects OLS model, we have more conclusive results. Product and marketing innovation show substitutability effect with the turnover per employee measure. Product innovation and co-operation with clients have complementary effect with both of the performance indicators. The result are similar to manufacturing industry with cross-sectional data. The outcome, that results are more similar to manufacturing industry results from the main empirical part of this paper, is because we have twice as more of manufacturing industry observations than service industry observations in our dataset. Only different results from the cross-sectional manufacturing industry dataset are results for product innovation together with co-operation with clients and marketing innovation together with co-operation with clients with TFP as the performance measure. These were inconclusive with cross-sectional data, however with panel data and fixed effects, they show complementary effect.

From the OLS fixed effects model results we can conclude that TFP is more reliable on time factor and it takes more time to innovations and co-operation with clients to benefit from each other and have a complementary effect on the productivity indicator.

[5] Due to several difficulties that the selection model has, when using panel data and fixed effect, the author has decided to use OLS model. Also, because turnover per employee indicator did not present selection problem, then we might not lose too much important information by using OLS method.

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