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COMPLEMENTARITIES IN PERFORMANCE BETWEEN PRODUCT INNOVATION, MARKETING INNOVATION AND COOPERATION WITH CLIENTS

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Complementarities in Performance Between Product Innovation, Marketing Innovation and Cooperation with Clients

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Abstract

This paper examines the complementary relationship between product innovation, marketing innovation and cooperation with clients, based on data from Estonian firms. The author evaluated complementary relationship in terms of its effect on the firm's total factor productivity. This study uses the Community Innovation Survey (CIS) and Estonian Business Register data from the years 2002–2012 and the Heckman selection model to research the complementarity effect between studied innovation activities using the supermodularity approach. The results show that product innovation and marketing innovation are complementary in the service industry, but in manufacturing industry there is lack of evidence for the effect of complementarity. Cooperation with clients showed inconclusive complementarity test results involving both innovation types in both industries. Using panel data as a robustness test showed more insights into the complementary effects between cooperation with clients and the studied forms of innovation. However, the results show a weak complementarity effect between cooperation and innovation and suggest that there is still no clear complementarity effect.

Keywords: Product innovation, Marketing innovation, Cooperation with clients, Complementarity, Performance

JEL Classification: C13, D24, L25, O30

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1. INTRODUCTION

Innovation is seen as one of the key drivers of economic growth in the last quarter of a century, and therefore firms and governments have been investing heavily in that field (Growth: Rationale…, 2007). Yet, there are considerable differences in the results of investing in innovation by different firms (Hall, 2011). One of the reasons for that might be a complementarity effect between different innovations. The 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 analysis was first introduced by Edgeworth (1897/2001) in a footnote from a paper 'La teorio pura del monopolio'. Schumpeter (1934) was one of the first researchers to argue that implementing certain innovation activities together can increase the total effect of the innovation on the performance of the firm more than others. Since Schumpeter's paper, there have been many empirical works studying the complementarity between different actions taken by firms.

In this paper, I study the complementary effect between product innovation, marketing innovation and cooperation with clients. Marketing innovation and product innovation are closely related to each other because marketing aims to increase sales of products or offer services to a 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 a higher positive effect on productivity growth than the effect of these two innovations separately. Therefore, they both should be complementary and coordination between these two activities can be highly beneficial for the firm.

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

There has been a limited amount of research to find complementarities between marketing innovation and product innovation (e.g. Junge et al., 2016). There have been a significant number of studies that have researched the effects of cooperation with external sources (e.g. Cassiman & Veugelers, 2006). However, there are not many papers that investigate three types of complementarities between innovation activities, especially between marketing, product innovation and cooperation with clients in an open economy that is as small and innovative as Estonia's (The Global…, 2017). This paper contributes to innovation studies by connecting Community Innovation Survey (CIS) data with the local business registry to have more precise performance data compared to the information available from the CIS. This is not possible for many countries and that is why many innovation studies only rely on the answers of innovation surveys (Mairesse & Mohnen, 2010). In this paper, the author aims to find out through econometric

analysis if marketing innovation, product innovation or cooperation with clients complement each other and add even more value to the firm together than separately.

The framework of this paper starts with a theoretical interpretation and overview of the empirical results of the effect of innovation and complementarity 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), Jaworski and Kohli (1990; 1993) and others. In the methodology part, the author highlights a mathematical and econometric explanation of the models and the supermodularity approach. The methodology part builds on the methods developed by Brynjolfsson and Milgrom (2013) and Milgrom and Roberts **(**1995). This will continue with a description of the datasets and the descriptive statistics of the variables that are used in the models. The final part is dedicated to the empirical results and the interpretation of those results.

The results suggest that only product innovation and marketing innovation in the service industry show a strong complementary effect. Studying the effects using panel data showed that cooperation has a complementary effect with marketing innovation and product innovation; however, the effect is only complementary if the innovations are added to cooperation with clients and not when adding cooperation to the innovations. Therefore, we do not find a clear complementary effect between the two forms of innovation and cooperation with clients.

2. LITERATURE REVIEW

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

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 in conjunction with other innovations. Therefore, when a firm has limited resources its budget expenditure should be as effective as possible in terms of results. Researching which innovations are complementary and implementing those innovations together can help the firm be more efficient with its budget.

Research tends to study the complementary effect of innovations from two main viewpoints. The *complementarities in use* approach studies which practices are implemented together and which benefit from each other, and the *complementarities in performance* approach studies how two or more practices together affect the performance of the firm (Colombo & Mosconi, 1995; Mohnen & Röller, 2005).

In this paper, the author will concentrate on studies that have used the *complementarities in performance* approach because the empirical part will study how complementarities affect the performance of the firm.

It is widely acknowledged that innovations and R&D improve the productivity of firms, but the productivity data has not always shown that result (Brynjolfsson & Hitt, 2000; Brynjolfsson & Hitt, 1998; Roach, 1987; Solow, 1987). What is known as the 'productivity paradox'[i] was first conceptualized by Solow (1987) and then popularized by an American study by Roach (1987), where investments in the IT field grew substantially in the 1980s, but the results were not as 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 using firm-level data 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.

This paper studies the complementarity effect of product and marketing innovations. The positive synergy between those two innovation activities is something that could be expected, 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 the relationship between product innovation and marketing, and they concluded that when firms are innovating in some product field, they always face some uncertainty about how the product will be perceived by consumers. Marketing interfaces can help to lower that uncertainty by integrating 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 either 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.

Innovations can also complement other actions the firm partakes in. The author is also studying the synergy between cooperation with clients and innovation to see if the firm benefits from attaining input from clients to produce innovations and through that achieves better performance with product innovation or marketing innovation.

Innovations are new ideas or concepts that have been commercially applied (Fagerberg, 2004). Therefore, 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 for production and implementation. Clients are usually the consumers of those innovations through products, and therefore should have good insights into what they want to buy and what they need from the products. 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. However, Laursen and Salter (2006) found that the effect of openness on performance is curvilinear (i.e. follows an inverted U-shape), and therefore too much cooperation can have a negative effect on the firm. The importance of external knowledge was also noted by Von Hippel (1988) based on the example of Japan user-based firms replacing US supplier-based firms in the semiconductor manufacturing field in the 1980s.

Jaworski and Kohli (1990) suggested, and later (1993) found empirical proof, that more market-oriented firms have a greater chance of innovating successfully in the product field and earn a greater premium from the sales of innovations than firms that do not study and implement market needs and this even holds in times of market turbulence and volatility. Berchicci (2013) found that external knowledge acquisition increases innovative performance only for firms that have a smaller internal knowledge stock, and in firms that have greater technological knowledge stock it will have a substitution effect with innovative activities. This result goes in line with other theories and empirical findings that suggest that market orientation can also limit innovation because customers usually give the same information to different firms and in that case, there can be only a few innovations to implement based on the feedback from clients (Lawton & Parasuraman, 1980; Christensen & Bower, 1996). In addition, customers often cannot even imagine that they need products that are radically innovative before they have been shown the new product (Tauber, 1974). Cooperation with clients can have a positive effect on the firm, but there are still many costs associated with cooperating with clients and negative aspects when introducing radical or revolutionary changes that also need to be taken into account.

From the review of the literature exploring innovations and their complementarity, we see that innovation is important so a firm can be as productive as possible, and its impact also differs when different forms of innovation are viewed together. The results and conclusions about the relationships and effects of innovation on the performance of the firm are mixed and depend considerably on the chosen data and methodology (Polder et al., 2010). Many effects between innovation activities depend on the context they are being developed in, with additional differences between industries and performance measures. This paper studies the relationships between product and marketing innovation, and cooperation with clients in the context of a small open economy and highlights differences in the relationships between innovation activities in the service and manufacturing industries.

3. METHODOLOGY

This study uses a supermodularity methodology to test for complementarities between product and marketing innovations and cooperation with clients. The methodology is based on the works of Brynjolfsson and Milgrom (2013) and Milgrom and Roberts **(**1995).

In the supermodularity approach, the author first creates dummy variables for the four combinations of two activities.[ii] This means there is a dummy variable for when an observation has none of the focus activities implemented; then two variables, where only one of the focus activities is implemented; and a dummy variable for when both of the focus activities are implemented. For example, with product and marketing innovations, the dummy variables are as follows: firm has not implemented product or 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). The performance variable is then regressed using a set of control variables and the innovation combination dummy variables using the Heckman selection model.

To econometrically test for complementarity/substitutability, the author uses one-sided z-tests to compare the estimated coefficients of activity combination dummies from the Heckman selection

model. Based on Brynjolfsson and Milgrom (2013) and Milgrom and Roberts **(**1995), the author will now provide a more detailed and methodological description of the supermodularity approach.

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. A 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 the two actions j and i are (weak) complements only if:

$$(1)\ f\ (1,1,x_{-ij}) - f\ (0,0,x_{-ij}) \geq [f\ (1,0,x_{-ij}) - f\ (0,0,x_{-ij})] + [f\ (0,1,x_{-ij}) - f(0,0,x_{-ij})]$$

That is, taking part in one 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 (weak) substitutability, the opposite needs to be true:

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

That is, taking part in one 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.

This complementarity test is separately completed for each of the activity pairs. The tests are conducted for product innovation in conjunction with marketing innovation, product innovation in conjunction with cooperation with clients, and marketing innovation in conjunction with cooperation with clients.

This paper studies the complementary effect of innovation activities on the performance of the firm. There are many different ways to measure a firm's performance (Syverson, 2011). The author of this paper has decided to use total factor productivity (TFP) as the measure of the firm's performance. TFP is a standard productivity measure, which was first introduced by Solow (1957). TFP measures how efficiently a firm uses its inputs to produce outputs. To estimate TFP, first the production function form needs to be chosen. 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 papers, that study TFP use the Cobb-Douglas function (Arnold, 2005). The reason for using the more restricted Cobb-Douglas function is that it is easier to implement and the results are usually not that different from the translog function. For the TFP calculations here, the author uses the Levinsohn-Petrin (2003) method with a proxy variable such as the sum of goods, raw materials and services, and the TFP calculations are performed separately for each 2-digit industry. All of the variables used here are also deflated using a 2-digit NACE GDP deflator.

To estimate the effects of the combinations of a firm's innovation activity on the performance of the firm, the author uses the Heckman selection model. The reason why the Heckman model is used in this paper is because the data is divided into those firms that implemented innovation in the period under analysis and to those who did not implement any innovations in that period. A selection problem arises from the fact that there might be underlying variables that affect the firm's decision/ability to innovate and if these are not taken into account then the traditional OLS, for only the sample of firms that innovated, will be biased and inconsistent. Heckman's (1976)

selection model helps to solve the selectivity problem by estimating the underlying probability of innovating based on the chosen variables.

The control variables in the selection model and the main model are based mainly on the combination of the works by Ballot et al. (2015) and Polder et al. (2010), 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 the previously mentioned papers, which are too subjective to the firm (e.g. different obstacles, that are present only when the firms are more active in those fields) and that are not collected for the Estonian firms (e.g. e-purchases and e-sales). In addition, the author has added two extra variables: a regional location dummy, which is included in Parisi et al. (2006), and European Union[iii] (EU) average innovation activity as the industry sector level effect indicator, and the author assumes that EU average innovation activity does not affect the performance measure but has an effect on the probability of the Estonian firms being innovative. Therefore, in this paper the author uses the EU average innovation activity via two-digit sector dummies, a dummy for belonging to a group of firms, an exporter dummy, the number of employees as a proxy for the size of the firm and a northern Estonia location dummy for the selection part of the model. The second step is to estimate the main model while considering the selection part of the model. For the main model, the author uses the studied activity combinations, number of employees as a proxy for the size of the firm, capital intensity, the first period performance indicator, the northern Estonia location dummy, innovation dummies that are not used in the activity combinations and an exporter dummy.

To control for the effects of other innovation types, the author added dummies to the main model for forms of innovation that are not the focus of this paper to control for their effect on the performance of the firm. Process innovation and organizational innovation dummies are added to all models. Since this paper studies the effects of the combination of innovation activity as pairs, then there is also a missing activity dummy, which is not included in the main pairwise analysis. For example, with the product innovation and cooperation dummy combinations, the marketing innovation dummy would be added as the control variable.

4. DATA AND DESCRIPTIVE STATISTICS

The author uses data from the European Community Innovation Survey (CIS) and the Estonian Business Register. The CIS is a harmonized micro level innovation survey conducted in the European Union to explore innovation activities in firms. Its questions are based on the Oslo Manual of the OECD. Innovation activities include technological innovations, which are production and process innovations and also non-technological innovations, which are organizational and marketing innovations (OECD Oslo Manual, 2005). There is additional information about cooperation with different external partners. The survey also collects information related to innovation activities. The survey started in 1992 and has been carried out according to different time intervals. Since 2002, the survey has been conducted after every 2 years (Glossary: Community…, 2017; Community Innovation…, 2017). Therefore, the definitions of product innovation, marketing innovation and cooperation with clients in this paper also follow the definitions of the respective questions in the CIS.

Product innovation means that the firm has introduced a good or a service that is completely new to the market or has made significant improvements or changes 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 or has made significant changes to the product, package, placement, promotion or pricing (OECD Oslo Manual, 2005).

Cooperation with clients means that the firm had meaningful input from clients to create innovations (OECD Oslo Manual, 2005).

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

In the empirical part of this paper, the author uses the CIS information on innovation activities from 2002 until 2012,[iv] because the survey has included questions about marketing innovation since 2002. All the CIS waves have been pooled. The information taken from the CIS and the Estonian Business Register that is used in the models is listed in Table 1.

The data is divided into groups, where firms have implemented at least one innovation type in a three-year CIS period, and other groups, where firms did not innovate in that certain CIS period. Out of the total observations, 61.6% of firms have implemented at least one innovation type. The percentage of firms who have implemented at least one innovation type is 63.4% for the manufacturing industry and 56.9% for the service industry.

From Table 1, we also see that overall innovative service and manufacturing industry observations have a similar ratio of product innovators, marketing innovators and cooperators with clients in their sample. The manufacturing industry has 3.7 percentage points more product innovators compared to the service industry, and the service industry has 4.5 percentage points more marketing innovators compared to the manufacturing industry. Cooperation with clients is almost the same for both industries with 19.3 per cent for the manufacturing industry and 20.4 per cent for the service industry. Although the manufacturing and service industries have a similar number of innovators by innovation type, the sample sizes per industry are quite different. From the whole sample, 65 per cent of the observations are for the manufacturing industry and 35 per cent are for the service industry. In addition, only slightly more than half of the service firms had innovations.

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**	**Manufacturing firms (3,740 obs.)**	**Service firms (1,970 obs.)**
Implemented innovation	Dummy variable, to indicate if the firm has implemented at least one innovation type (0,1)	63.4	56.9
Logarithmic TFP	Surveyed logarithmic TFP of the firm for the last year	9.425 *(9.354)*	9.723 (*9.462*)
Start logarithmic TFP	Surveyed logarithmic TFP of the firm for the first year	9.382 (*9.3*)	9.738 (*9.482*)
Product innovation	Dummy variable, to indicate if the firm has implemented product innovation during the survey period (0,1)	55.2 (*34.9*)	51.5 (*29.3*)
Marketing innovation	Dummy variable, to indicate if the firm has implemented marketing innovation during the survey period (0,1)	43.7 (*27.7*)	48.2 (*27.4*)
Cooperation with clients	Dummy variable, to indicate if the firm has cooperated with clients during the survey period (0,1)	19.3 (*11.8*)	20.4 (*10.9*)
Process innovation	Dummy variable, to indicate if the firm has implemented process innovation during the survey period (0,1)	66.4 (*42.1*)	55.9 (*31.8*)
Organizational innovation	Dummy variable, to indicate if the firm has implemented organizational innovation during the survey period (0,1)	50.2 (*31.8*)	61.3 (*34.9*)
Size	Logarithmic number of employees in the firm	4.02 (*3.8*)	3.62 (*3.5*)
Capital intensity	Logarithmic capital and labour ratio	9.09 (*8.85*)	8.85 (*8.84*)
North Estonia	Dummy variable, to indicate if the firm is registered in northern Estonia (0,1)	45.7 (*45.2*)	75.5 (*70.0*)
Export	Dummy variable, to indicate if the firm is an exporter (0,1)	89.9 (*86.3*)	70.9 (*65.9*)
Group	Dummy variable, to indicate if the firm belongs to a group (0,1)	48.8 (*40.1*)	55.7 (*46.1*)
EU average innovation activity**	EU average innovation activity two-digit EMTAK2008/NACE sector dummies	0.391	0.286

Notes: *The author has excluded firms with less than 10 employees. ** The author has excluded government, medical and teaching sectors. The binary variable results are in percentages.
Source: CIS and the Estonian Business Register, calculations by the author

The data also has a possible endogeneity problem between innovation input variables and the performance measure. Most of the papers that study the complementary effects of innovations have the same type of endogeneity problem (e.g. Vahter and Masso (2012) and Ballot et al. (2015)). To address the endogeneity problem, the author conducts a robustness test using a fixed-effects model based on panel data without separating the two main industries. This robustness test provides more insights into how the effects of innovations and cooperation change over time for the firms. However, one could argue that the fixed-effects model is a rather limited solution for the endogeneity problem and the results can still be biased.

5. REGRESSION AND SUPERMODULARITY TEST RESULTS

Table 2, 3 and 4 present the unconditional effects of different combinations of product innovation, marketing innovation and cooperation with clients for the whole sample. Most of the observations are in the category where none of the two studied activities are implemented, and this is also logical because almost half of the observations are about firms that did not implement any innovation types in the studied period. The groups do not have any single dominant strategy for the studied activities, but the cooperation with clients sample is much smaller than the product or marketing innovation samples.

In Table 2, the author presents the mean TFP for product and marketing innovation combinations. Group 1 with no product innovation and no marketing innovation has the lowest TFP, as expected. The effects of marketing and product innovation are positive on the mean TFP and when both product and marketing innovation are implemented then the mean TFP is the highest.

Table 2. Product and marketing innovation combinations: descriptive statistics for logarithmic TFP

Category	**Obs.**	**Mean**	**Std. Dev.**
Group 1: No Product and Marketing Innovation	2,363	9.305	1.108
Group 2: Only Marketing Innovation	403	9.497	1.125
Group 3: Only Product Innovation	606	9.504	1.026
Group 4: Both Innovations	641	9.601	1.068

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

In Table 3, the author has unconditional TFP means for the product innovation and cooperation with clients group. In this case, again Group 1, with no product innovation and no cooperation with clients, has the lowest mean TFP. However, the highest mean performance measure is for Group 2 that cooperates with clients and has not adopted product innovation. This might be due to having quite a small sample size for firms that have cooperated with clients and not implemented any product innovation.

Table 3. Product innovation and cooperation with clients combinations: descriptive statistics for logarithmic TFP

Variable	**Obs.**	**Mean**	**Std. Dev.**
Group 1: No Product Innovation and Cooperation with Clients	2,691	9.313	1.109
Group 2: Only Cooperation with Clients	75	10.050	1.026
Group 3: Only Product Innovation	874	9.527	1.055
Group 4: Both Innovation Activities	373	9.617	1.032

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

The unconditional means of marketing innovation and cooperation with clients groups are presented in Table 4. As in previous results, Group 1, with no cooperation with clients and no

marketing innovation, has the lowest mean performance measure. Cooperation with clients and marketing innovation separately have higher performance measures, but the highest performance measures are for Group 4, which have implemented marketing innovations and are also cooperating with clients.

Table 4. Marketing innovation and cooperation with clients combinations: descriptive statistics for logarithmic TFP

Variable	**Obs.**	**Mean**	**Std. Dev.**
Group 1: No Marketing Innovation and Cooperation with Clients	2,769	9.321	1.094
Group 2: Only Cooperation with Clients	200	9.678	1.059
Group 3: Only Marketing Innovation	796	9.518	1.106
Group 4: Both Innovation Activities	248	9.698	1.031

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

The paper now continues with regression results to get a better idea of how product and marketing innovation and cooperation with clients affect the performance measure in conjunction with other control variables.

The results of the complete regression models are presented in Appendix 1 for the manufacturing industry and in Appendix 2 for the service industry. Here the author only highlights 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 action pair.

The author uses a one-sided z-test based on the supermodularity approach to study the complementarity or substitutability effects between the action pairs. First, regression results are given for product innovation and marketing innovation combinations. The results for manufacturing and service firms are presented in Table 5. In the manufacturing industry, none of the combinations of marketing innovation and product innovation have a statistically significant[v] effect on the performance measure that is different from the base category of implementing none of the two studied innovations. The effect of product innovation and both, marketing and product innovation separately, not being present in the TFP indicator, might be explained by the theory described by Brynjolfsson and Hitt (2000), which states that two complementary activities can increase other aspects of the firm that are not present in the productivity measurement.

For the service industry, marketing and product innovation together is the only statistically significant combination and it leads to higher performance. This suggests a complementary effect between product and marketing innovation for the service industry.

Table 5. Product and marketing innovation combinations: performance function estimation results

	Manufacturing	Service
	TFP	TFP
Main model		
Only Marketing Innovation	-0.037	-0.021
	(0.027)	(0.044)
Only Product Innovation	0.045	0.056
	(0.028)	(0.044)
Product and Marketing Innovation	-0.029	0.142***
	(0.029)	(0.049)
First period TFP	0.868***	0.911***
	(0.012)	(0.013)
Size	0.031**	-0.021
	(0.013)	(0.015)
Capital Intensity	0.025***	-0.010
	(0.006)	(0.009)
North Estonia	-0.005	0.074**
	(0.021)	(0.036)
Organizational Innovation	0.071***	0.064*
	(0.021)	(0.034)
Cooperation with clients	-0.024	-0.036
	(0.033)	(0.047)
Process Innovation	0.009	-0.087**
	(0.020)	(0.036)
Export	0.052*	0.069**
	(0.026)	(0.031)
Observations	3740	1970
Log Likelihood	-3631.6	-2112.4
Chi-squared	6793.0	9432.8

Notes. Standard errors are clustered by firm id. * significant at 10%; ** significant at 5%; *** significant at 1%. The base category for the studied action combinations is no product innovation and no marketing innovation. Selection model variables in conjunction with constant variables are omitted from this table. The full models are presented in Appendix 1 and 2.
Source: CIS and the Estonian Business Register, calculations by the author

The different results between industries indicates that marketing innovation in conjunction with product innovation is more important for the service industry than for manufacturing industry firms. Winter and Wall (2006) and Stehrer et al. (2014) also found in their studies that marketing activities benefit more service firms than manufacturing firms due to the differences in functionality and consumption of produced products between both sectors.

The regression results in Table 6 are for product innovation and cooperation with clients combinations. In the case of manufacturing firms, none of the combinations have any statistically significant effect compared to the base category of no product innovation and cooperation with clients. This goes with previous combination regression results of product and marketing innovation. In the service industry, the author finds that only product innovation and no cooperation with clients have a statistically significant positive effect on TFP. Therefore, cooperation with clients alone does not have a statistically significant effect on the TFP measure. This is logical because cooperation with clients means that the firm has acquired information from clients about

their needs and what they should innovate, and if this is not used to produce or improve any product, then there is no gain to be received from the cooperation.

Table 6. Product innovation and cooperation with clients combinations: performance function estimation results

	Manufacturing	Service
	TFP	TFP
Main model		
Only Cooperation with clients	-0.016	-0.028
	(0.069)	(0.092)
Only Product Innovation	0.034	0.091**
	(0.023)	(0.040)
Product Innovation and Cooperation	0.007	0.060
	(0.034)	(0.049)
First period TFP	0.868***	0.910***
	(0.013)	(0.013)
Size	0.031***	-0.021
	(0.012)	(0.015)
Capital Intensity	0.025***	-0.009
	(0.007)	(0.009)
North Estonia	-0.004	0.074**
	(0.020)	(0.036)
Organizational Innovation	0.071***	0.062*
	(0.022)	(0.034)
Marketing Innovation	-0.055**	0.026
	(0.022)	(0.034)
Process Innovation	0.010	-0.087**
	(0.020)	(0.037)
Export	0.053**	0.068**
	(0.027)	(0.031)
Observations	3740	1970
Log Likelihood	-3631.9	-2113.5
Chi-squared	6213.1	9607.7

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 cooperation with clients. Selection model variables in conjunction with constant variables are omitted from this table. Full models are presented in Appendix 1 and 2.
Source: CIS and the Estonian Business Register, calculations by the author

The last regression results in Table 7 are for marketing innovation and cooperation with clients combinations. Marketing innovation and cooperation with clients together are statistically significant and have a negative correlation with TFP in the manufacturing industry. Other research has opposing results that cooperation with clients and marketing innovation tend to correlate with higher performance, although they also mention that the results vary and do not have as strong and clear an effect has expected (Chesbrough, 2006; Cassiman & 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 cooperation being implemented. The cause for the negative effect could be from the learning-by-using effect of innovations and cooperation, which was studied by Bourke and Roper (2016) in regard to technological innovations. Innovations have high costs and can have a negative effect on the performance of the firm in the first periods of implementation and after time yield a positive effect, when the firm is

more accustomed to the innovation. For the service industry, none of the studied combinations show statistically significant differences from the base category of not implementing any of the current innovation actions.

Table 7. Marketing innovation and cooperation with clients combinations: performance function estimation results

	Manufacturing	Service
	TFP	TFP
Main model		
Only Cooperation with clients	-0.010	-0.057
	(0.049)	(0.067)
Only Marketing Innovation	-0.050**	0.017
	(0.024)	(0.038)
Marketing Innovation and Cooperation	-0.090**	0.011
	(0.040)	(0.064)
First period TFP	0.868***	0.911***
	(0.012)	(0.013)
Size	0.031**	-0.021
	(0.013)	(0.015)
Capital Intensity	0.025***	-0.009
	(0.006)	(0.009)
North Estonia	-0.004	0.074**
	(0.021)	(0.036)
Organizational Innovation	0.071***	0.063*
	(0.021)	(0.034)
Product Innovation	0.032	0.092**
	(0.022)	(0.036)
Process Innovation	0.010	-0.086**
	(0.020)	(0.036)
Export	0.053**	0.068**
	(0.026)	(0.031)
Observations	3740	1970
Log Likelihood	-3631.8	-2113.3
Chi-squared	6817.5	9487.5

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 cooperation with clients. Selection model variables in conjunction with constant variables are omitted from this table. Full models are presented in Appendix 1 and 2.
Source: CIS and Estonian Business Register, calculations by the author

Product innovation shows the highest effect on the performance of the firm from the studied innovation activities for both industries. Hall (2011) also found that product innovation has one of the largest effects on the performance of the firm from different innovation types. Marketing innovation leads to lower performance in the short term. This goes in line with the theory based on Brynjolfsson and Hitt (2000) that the effect of marketing innovations has more effect on the qualities of the product or firm that are not presented in the productivity of the firm but are present in the sales of the firm. Therefore, it can have a negative effect on the productivity of the firm, but still can have a positive effect on the overall sales of the firm. Cooperation with clients has the lowest effect on firm performance and mainly leads to a lower performance in the short term, which indicates that cooperation with clients has high costs for the firm. Overall, technological

innovations have shown to have a higher effect on the performance of firms than non-technological innovations (e.g. Vahter and Masso (2012) and Schmidt and Rammer (2007)).

From the control variables, the author finds that the size of the firm is statistically significant for TFP only in the manufacturing industry. The effect of size on the TFP measure is positive. Polder et al. (2010) found that the effect of size has different results in both industries and can have a positive effect on the productivity of manufacturing firms, but the opposite for the service industry.

Capital intensity is statistically significant and has a positive effect on the performance measure in the manufacturing industry. This result matches the works of Datta et al. (2005), Mahesha (2008) and Polder et al. (2010). However, for the service industry, capital intensity is not statistically significant.

The northern Estonia dummy is statistically significant and has a positive effect on the TFP measure for the service industry. For the manufacturing industry, the northern Estonia indicator is not statistically significant. Manufacturing firms are less dependent on location because they are producing physical goods and most likely without a 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, the service industry acts on the orders of the customer and is more customer specific, and therefore services are targeted for more specific end-users compared to the manufacturing industry, which is not as customer specific and targets a segment of production. In addition, the service industry is more skilled labour-intensive and, as mentioned before, most of the skilled workforce resides in northern Estonia (Liao et al., 2007; Statistics Estonia Database, 2017). Koh and Riedel (2014) found that service firms are more dependent on location than manufacturing firms. These might be the reasons why most of our (76%) innovative service industry firms are gathered in northern Estonia. However, with such a high percentage of innovative service firms clustered in northern Estonia, it is difficult to argue whether the firm has higher productivity from being registered in northern Estonia or that firms that have higher productivity are clustered in northern Estonia. In addition, the fact that this is the firm's registered address as the dummy and that firms can have businesses in other parts of the country needs to be taken into consideration.

Organizational innovation is statistically significant for both industries. The positive effect of organizational innovation on the performance of the firm was also found by Polder et al. (2010) and Ballot et al. (2015).

Process innovation is statistically insignificant for the manufacturing industry performance indicator. Cassiman et al. (2010) and Crespi et al. (2007) also found no process innovation to be statistically significant for productivity in the case of manufacturing firms. They suggested that, since process innovation is a change of organizational processes and combinations 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. However, process innovation in the service industry has a statistically significant negative effect on the TFP measure. This negative effect can be explained using the results from the work by Polder et al. (2010), where they found that process innovation in the service industry in conjunction with product innovation has a negative effect on the TFP measure. Therefore, the statistically negative effect on the TFP measure can come from the concurrence of product and process innovation. In addition, there can

be an initial loss of productivity from implementing a new process as workers need to get used to the new process and learn to use it (Bourke & Roper, 2016).

Lastly, the exporter dummy is statistically significant and has a positive effect on performance measurement in the service industry and manufacturing industry. Exporting has been found to have a 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).

Table 8 shows the results of the complementarity test using the supermodularity approach by industry and action pair. The complementarity test for product and marketing innovation gives inconclusive results. Therefore, there is no evidence that the two innovations have a complementary or substitutability effect with each other when their effect is studied with TFP as the performance measure. The reason for the inconclusive results might be that this paper studies the firms of quite a small country and the strain of implementing two major innovation types in three years can be too demanding for firms in a small country, and therefore the performance of the firm does not increase in the short term when implementing two innovations together. Klein and Sorra (1996) find that the implementation effectiveness of innovations depends on the climate the organizations operates in and how the employees learn to use the innovations. Implementing two innovation types in a short period will make it even more difficult for the workers to get used to the new activities that come in conjunction with new innovations, and therefore lose the benefit from those innovations. In addition, if a firm innovates a new product, then it might not need to implement marketing innovation to sell that product. Since they already have an innovative product that may be a new selling point on its own, then additional marketing innovation does not have as much effect on the performance of the firm as when no product innovation is present.

Table 8. Results of the complementarity test for each action pair and industry

Industry	Action pairs	TFP
Manufacture	Product and Marketing Innovation	Inconclusive
Service	Product and Marketing Innovation	Complementarity*
Manufacture	Product Innovation and Cooperation	Inconclusive
Service	Product Innovation and Cooperation	Inconclusive
Manufacture	Marketing Innovation and Cooperation	Inconclusive
Service	Marketing Innovation and Cooperation	Inconclusive

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

For the service industry firms, the complementarity test between product innovation and marketing innovation shows a complementary effect. This result is in line with the findings by Junge et al. (2016).

The contradiction between the results in the service industry and the manufacturing industry might mean that in the service industry the positive effect of new product function and characteristics is elevated by the smaller changes in the service design and appearance. In the manufacturing industry the changes to the functionality and the characteristics of the product are most important for the

productivity of the firm. Therefore, the design and appearance changes of the product do not have complementary effect in conjunction with the functional changes in the product.

This was also found by Winter and Wall (2006) in the food and beverages industry, and Stehrer et al. (2014) in their study where they found that advertising and marketing is more important to the service industry compared to the manufacturing industry. In addition, as mentioned above in regard to the location of service and manufacturing sector firms, service firms in Estonia produce their services especially for end-users, while manufacturing firms are not that tightly connected to the end-users, and therefore marketing innovation and product innovation can have a greater complementary effect in the service industry compared to the manufacturing industry, as they have a greater need for marketing innovations.

The complementarity test for product innovation and cooperation with clients in the manufacturing industry shows inconclusive results. According to different theories, cooperation with clients can have positive and negative effects on innovation performance. Laursen and Salter (2006) argue that the effect of cooperation has a curvilinear shape and different levels of cooperation can have negative or positive effects on the performance of the firm. Berchicci (2013) found that cooperation is only positive if the firm has a low level of internal knowledge stock and hinders the performance of innovation activities, when the firm has high levels of internal knowledge stock. In addition, the fact that quite a small portion of the sample includes observations where firms have cooperated with clients needs to be considered. Low levels of formal cooperation with clients creates uneven samples for product innovation and cooperation with clients combinations. The sample here has 75 observations that have implemented only cooperation with clients and 373 observations have product innovation in conjunction with cooperation with clients in both manufacturing and service industries. This might be one reason why product innovation and cooperation with clients have inconclusive results for the manufacturing industry and service industry.

However, it could also be argued that the complementary effect of cooperation with clients can occur before the final innovation output and production function and that is the reason why the complementarity tests analysing the relationships between innovation output and performance show inconclusive results. Cooperation with clients could affect the effectiveness of R&D to produce innovations. Roper et al. (2008) found that knowledge sourcing from customers increases the probability of product innovation and also the probability of innovating successfully.

These previously mentioned statements might also be the reason why the complementarity test for marketing innovation and cooperation with clients also yields inconclusive results. Therefore, these results suggest that there is no clear short-term complementarity effect between innovations and cooperation with clients.

6. ROBUSTNESS TESTS

As a robustness analysis, the author constructed panel data from the previous cross-sectional dataset. To obtain a viable dataset for the analysis, the author chose not to separate between the manufacturing and service industries for the following tests and kept the firms that had at least three consecutive CIS results.

The analysis is first conducted using a random effects model[vi] to study the complementarity effect between product innovation, marketing innovation and cooperation with clients using the panel data.

The regression results for all of the action combinations are presented in Appendix 3. The results do not differ much from the cross-sectional data results; however, the fact that the analysis of the manufacturing and service industries was separate in the main empirical part needs to be taken into account.

Table 9 presents the complementarity test with the results from the supermodularity approach for complementarities between the studied actions. None of the action pairs give any conclusive results.

Table 9. Selection model with panel data results for the complementarity test for each action pair

Action pairs	TFP
Product and Marketing Innovation	Inconclusive
Product Innovation and Cooperation	Inconclusive
Marketing Innovation and Cooperation	Inconclusive

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

To get more thorough idea of how the innovations and cooperation with clients complement each other over time, then the OLS fixed-effects model[vii] is also used.

The fixed-effects OLS model in Table 10 shows more conclusive results. Product and marketing innovation show a complementarity effect with cross-sectional data, but with the panel data the test shows inconclusive results. The inconclusive results might come from the fact that the complementarity test between product and marketing innovation also showed inconclusive effects with cross-sectional data for the manufacturing industry and the sample is approximately 2/3 manufacturing firms and their effect might dominate the test with the panel data.

Table 10. OLS fixed-effects model with panel data results from the complementarity test for each action pair

Action pairs	TFP
Product and Marketing Innovation	Inconclusive
Product Innovation and Cooperation	Complementarity*
Marketing Innovation and Cooperation	Complementarity*

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

Product innovation and cooperation with clients and marketing innovation and cooperation with clients show a complementary effect between them using the panel data. This result is different from the cross-sectional data tests, where the results were inconclusive. This suggests that the complementary effect might need to be looked at over longer periods and there might exist a

learning-by-using effect that takes time for the benefit from the synergy between innovation and cooperation to emerge. However, the complementarity between the innovations exists only if innovation is added to the cooperation with clients (see Appendix 4), because the effect of cooperation on its own is negative on performance (e.g. the product innovation coefficient (0.051) on its own is larger than product innovation with cooperation (0.03), but the test shows complementarity because only cooperation with clients has a negative coefficient). Therefore, because of the weak complementarity effect using the panel data and inconclusive results with the cross-sectional data, this suggests that there is no clear complementarity effect between the innovations and cooperation with clients. The inconclusive results might be due to the low level of cooperation with clients and the inverted U-shape effect of cooperation on the performance of the firm or/and that the complementarity effect of cooperation with clients occurs already when the firm converts R&D into an innovation output (Laursen & Salter, 2006; Roper et al., 2008).

The OLS fixed-effects model results indicate that the effect of synergy between innovations and cooperation with clients is more reliable on the time factor, although the tests only show one-sided complementarity (i.e. firm's performance increases more when innovations are added to cooperation with clients, but not vice-versa) between the innovations and cooperation with clients, which suggests there does not exist a clear complementary effect between innovations and cooperation with clients.

7. CONCLUSIONS AND DISCUSSION

This paper studied the complementary effects of marketing innovation, product innovation and cooperation with clients on the performance of the firm. The author analysed the effects separately for the manufacturing industry and the service industry firms to give additional insight into how the complementarity effects between product innovation, marketing innovation and cooperation with clients differ between the two industries.

The author finds that there is no universal complementarity or substitutability between product innovation, marketing innovation and cooperation with clients. The complementary effects between innovation activities differ across industries and time dimensions.

The complementarity test results show that product innovation with marketing innovation do not have complementary effect between them in the manufacturing industry. The reason for that could be that innovative products also have marketing value and do not need any new marketing innovations for the firm to have more benefit from the product innovation. Furthermore, the performance gain from implementing marketing and product innovation together might be lost due to the strain and learning required due to implementing two innovations in a relatively short period. However, the author did find a complementary effect on the TFP measure between product and marketing innovations in the service industry. This indicates that service firms, which implement product innovation in conjunction with marketing innovation in a three-year period, experience higher productivity. The difference between industries can be explained by the nature of the service industry, where incremental innovations and marketing activities are more important for the performance of the firm than in the manufacturing industry (Winter & Wall, 2006; Stehrer et al., 2014).

Cooperation with clients has inconclusive results in the complementarity test with marketing innovation and product innovation in both industries. Cooperation with clients was expected to enhance the effect of marketing innovation and/or product innovation, but it had inconclusive results in the complementarity test. Roper et al. (2008) found that forward knowledge sourcing from customers increased the effectiveness of R&D to produce an innovation output. This would explain why there is no complementary effect between innovations and cooperation with clients because the complementary effect could already occur in earlier stages of the innovation production. Additionally, the result could be affected by the curvilinear effect of openness on the performance of the firm that was found by Laursen and Salter (2006) and Berchicci (2013) in relation to the effect of cooperation with clients, where the innovation performance of the firm is only affected positively, when the firm has low levels of internal knowledge stock, and with high levels of internal knowledge stock there is an opposite effect on the performance of innovations. Consequently, cooperation with clients could have a complementary effect with some of the firms in the sample and a substitutability effect with other firms because of some other underlying properties that are not controlled for and give inconclusive results when all of those firms are pooled for the tests.

In the robustness test, the author added a panel data aspect to the model, pooling manufacturing and service industry data to get a viable dataset. The results add additional information about the relationship between cooperation with clients and marketing and product innovation. The complementarity test shows a complementary relationship between cooperation with clients and innovations using panel data. The cross-sectional data analysis showed inconclusive results for those two action pairs. However, the results are only one-sided; in other words, the complementarity effect only exists when cooperation is already present and then innovations are added. If the firm innovates first in product or marketing field and later cooperates with clients, then there does not exist complementarity effect between innovations and cooperation with clients. This indicates a lack of complementarity between the innovations and cooperation with clients, even when the complementarity effect is studied using panel data. These results show that the synergy between cooperation with clients and innovations increases with time, but it is still not enough to suggest a complementarity effect between the innovations and cooperation with clients.

It must be mentioned here that there are several issues with the data that might affect the results. Hence, not all of the findings apply to all firms. First, there is a problem involved in having cross-sectional data in the main empirical part. As a result, the analysis does not observe a firm's exits and entries from the market and it is also not possible to study the longer-term effects of innovations and cooperation separately for each industry due to the sample sizes. Second, it cannot be claimed that the studied actions only affect the performance of the firm and that firm performance does not affect implementing and benefiting from the innovations. Third, in the case of studying the effects of product innovation and cooperation with clients, the author encounters the under representation of observations, where the firm only cooperates with clients and conducts no product innovation. Finally, the literature review suggests that works on the complementarity effect between innovations and similar actions have quite varying results, and papers with slightly different models get diverse results when studying the effects of the same actions. This suggests that the results found in this paper are sensitive to the methods used and specific to the firms in the sample country.

Further research should include a CDM model to study the effects of product and marketing innovation and cooperation with clients. This would provide greater insights into the sensitivity of

the models used in this paper and show whether the results hold up with other model specifications. In addition, alternative cooperation factors could be more thoroughly studied at greater depth and breadth and also compare the effect of different forms of cooperation on marketing and product innovation. Furthermore, a longitudinal case study of several firms to analyse the costs of innovations and cooperation, the intensity of non-technological innovations and the learning-by-using effect of innovations would complement this paper well. The results from those case studies would give a more precise idea of how innovations and cooperation change the firm and through what exactly the complementary effect is achieved.

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APPENDIX: REGRESSION RESULTS

Appendix 1. Manufacturing industry performance function estimation results: combinations of product and marketing innovation and cooperation with clients

	Product and Marketing innovation	Product innovation and cooperation with clients	Marketing innovation and cooperation with clients
	TFP	TFP	TFP
Main model			
Only Marketing Innovation	-0.037		
	(0.027)		
Only Product Innovation	0.045		
	(0.028)		
Product and Marketing Innovation	-0.029		
	(0.029)		
Only Cooperation with clients		-0.016	
		(0.069)	
Only Product Innovation		0.034	
		(0.023)	
Product Innovation and Cooperation		0.007	
		(0.034)	
Only Cooperation with clients			-0.010
			(0.049)
Only Marketing Innovation			-0.050**
			(0.024)
Marketing Innovation and Cooperation			-0.090**
			(0.040)
First period TFP	0.868***	0.868***	0.868***
	(0.012)	(0.013)	(0.012)
Size	0.031**	0.031***	0.031**
	(0.013)	(0.012)	(0.013)
Capital Intensity	0.025***	0.025***	0.025***
	(0.006)	(0.007)	(0.006)
North Estonia	-0.005	-0.004	-0.004
	(0.021)	(0.020)	(0.021)
Organizational Innovation	0.071***	0.071***	0.071***
	(0.021)	(0.022)	(0.021)
Process Innovation	0.009	0.010	0.010
	(0.020)	(0.020)	(0.020)
Product Innovation			0.032
			(0.022)
Marketing Innovation		-0.055**	
		(0.022)	
Cooperation with clients	-0.024		
	(0.033)		
Export	0.052*	0.053**	0.053**
	(0.026)	(0.027)	(0.026)
Constant	1.065***	1.069***	1.068***
	(0.114)	(0.118)	(0.113)
Selection model			
EU average innovation activity	0.752***	0.750***	0.750***
	(0.203)	(0.161)	(0.203)
Size	-0.213***	-0.213***	-0.213***
	(0.038)	(0.024)	(0.038)

Group	-0.089	-0.090*	-0.090
	(0.069)	(0.047)	(0.068)
Export	-0.036	-0.036	-0.036
	(0.086)	(0.064)	(0.086)
North Estonia	0.227***	0.227***	0.227***
	(0.070)	(0.043)	(0.070)
Constant	1.338***	1.337***	1.337***
	(0.167)	(0.116)	(0.167)
$\sqrt{\rho}$ Constant	-0.745***	-0.746***	-0.748***
	(0.125)	(0.130)	(0.124)
$\ln(\sigma)$ Constant	-0.755***	-0.754***	-0.754***
	(0.046)	(0.046)	(0.046)
Observations	3740	3740	3740
Log Likelihood	-3631.6	-3631.9	-3631.8
Chi-squared	6793.0	6213.1	6817.5

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

Appendix 2. Service industry performance function estimation results: combinations of product and marketing innovation and cooperation with clients

	Product and Marketing innovation	Product innovation and cooperation with clients	Marketing innovation and cooperation with clients
	TFP	TFP	TFP
Main model			
Only Marketing Innovation	-0.021		
	(0.044)		
Only Product Innovation	0.056		
	(0.044)		
Product and Marketing Innovation	0.142***		
	(0.049)		
Only Cooperation with clients		-0.028	
		(0.092)	
Only Product Innovation		0.091**	
		(0.040)	
Product Innovation and Cooperation		0.060	
		(0.049)	
Only Cooperation with clients			-0.057
			(0.067)
Only Marketing Innovation			0.017
			(0.038)
Marketing Innovation and Cooperation			0.011
			(0.064)
First period TFP	0.911***	0.910***	0.911***
	(0.013)	(0.013)	(0.013)
Size	-0.021	-0.021	-0.021
	(0.015)	(0.015)	(0.015)
Capital Intensity	-0.010	-0.009	-0.009
	(0.009)	(0.009)	(0.009)
North Estonia	0.074**	0.074**	0.074**
	(0.036)	(0.036)	(0.036)
Organizational Innovation	0.064*	0.062*	0.063*
	(0.034)	(0.034)	(0.034)
Process Innovation	-0.087**	-0.087**	-0.086**
	(0.036)	(0.037)	(0.036)
Product Innovation			0.092**
			(0.036)
Marketing Innovation		0.026	
		(0.034)	
Cooperation with clients	-0.036		
	(0.047)		
Export	0.069**	0.068**	0.068**
	(0.031)	(0.031)	(0.031)
Constant	0.778***	0.773***	0.773***
	(0.135)	(0.136)	(0.135)
Selection model			
EU average innovation activity	1.058***	1.056***	1.056***
	(0.278)	(0.278)	(0.278)
Size	-0.094**	-0.094**	-0.094**
	(0.046)	(0.046)	(0.046)
Group	-0.347***	-0.346***	-0.346***

	(0.090)	(0.090)	(0.090)
Export	0.317***	0.317***	0.317***
	(0.087)	(0.087)	(0.087)
North Estonia	-0.099	-0.099	-0.099
	(0.100)	(0.100)	(0.100)
Constant	0.986***	0.986***	0.986***
	(0.189)	(0.189)	(0.189)
$\sqrt{\rho}$ Constant	0.260**	0.256**	0.255**
	(0.107)	(0.108)	(0.107)
$\ln(\sigma)$ Constant	-0.705***	-0.705***	-0.705***
	(0.048)	(0.048)	(0.048)
Observations	1970	1970	1970
Log Likelihood	-2112.4	-2113.5	-2113.3
Chi-squared	9432.8	9607.7	9487.5

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

Appendix 3. Performance function estimation results with Heckman random effects model with panel data: combinations of product, marketing innovation and cooperation with clients

	Product and Marketing innovation	Product innovation and cooperation with clients	Marketing innovation and cooperation with clients
	TFP	TFP	TFP
Only Marketing Innovation	-0.015		
	(0.030)		
Only Product Innovation	0.053*		
	(0.028)		
Product and Marketing Innovation	0.039		
	(0.031)		
Only Cooperation with clients		-0.060	
		(0.061)	
Only Product Innovation		0.051**	
		(0.024)	
Product Innovation and Cooperation		0.017	
		(0.039)	
Only Cooperation with clients			-0.061
			(0.052)
Only Marketing Innovation			-0.022
			(0.025)
Marketing Innovation and Cooperation			-0.041
			(0.037)
Size	-0.040**	-0.041**	-0.041**
	(0.018)	(0.018)	(0.018)
Capital Intensity	0.003	0.003	0.003
	(0.007)	(0.007)	(0.007)
First period TFP	0.846***	0.846***	0.846***
	(0.014)	(0.015)	(0.014)
North Estonia	0.033	0.033	0.033
	(0.021)	(0.021)	(0.021)
Organizational innovation	0.048**	0.048**	0.049**
	(0.022)	(0.022)	(0.022)
Process Innovation	-0.018	-0.018	-0.017
	(0.022)	(0.022)	(0.022)
Product Innovation			0.054**
			(0.023)
Marketing Innovation		-0.015	
		0.022	
Cooperation with clients	-0.040		
	(0.034)		
Export	0.050*	0.050*	0.050*
	(0.027)	(0.028)	(0.028)
Inverse Mills ratio	-0.199**	-0.199**	-0.199**
	(0.086)	(0.086)	(0.086)
Constant	1.618***	1.618***	1.622***
	(0.194)	(0.194)	(0.194)
Observations	2338	2338	2338
Chi-squared	5978.2	6064.5	5957.7

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

Appendix 4. Performance function estimation results with OLS fixed-effects model with panel data: combinations of product, marketing innovation and cooperation with clients

	Product and Marketing innovation	Product innovation and cooperation with clients	Marketing innovation and cooperation with clients
	TFP	TFP	TFP
Only Marketing Innovation	-0.016		
	(0.029)		
Only Product Innovation	0.069**		
	(0.028)		
Product and Marketing Innovation	0.028		
	(0.028)		
Only Cooperation with clients		-0.124**	
		(0.053)	
Only Product Innovation		0.051**	
		(0.025)	
Product Innovation and Cooperation		0.030	
		(0.042)	
Only Cooperation with clients			-0.085
			(0.052)
Only Marketing Innovation			-0.043*
			(0.023)
Marketing Innovation and Cooperation			-0.046
			(0.040)
Size	0.033	0.033	0.032
	(0.036)	(0.036)	(0.036)
Capital Intensity	0.001	0.001	0.001
	(0.014)	(0.014)	(0.014)
First period TFP	0.186***	0.188***	0.187***
	(0.038)	(0.038)	(0.038)
North Estonia	-0.147	-0.143	-0.146
	(0.142)	(0.141)	(0.141)
Organizational Innovation	0.009	0.009	0.012
	(0.023)	(0.023)	(0.022)
Process Innovation	0.019	0.021	0.021
	(0.021)	(0.021)	(0.021)
Product Innovation			0.063***
			(0.023)
Marketing Innovation		-0.028	
		(0.021)	
Cooperation with clients	-0.043		
	(0.035)		
Export	-0.010	-0.009	-0.008
	(0.040)	(0.040)	(0.040)
Constant	7.584***	7.580***	7.586***
	(0.430)	(0.430)	(0.432)
Observations	2551	2551	2551
Log Likelihood	-495.2	-493.9	-493.8
R-squared	0.0445	0.0455	0.0455

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

[i] Also known as Solow computer paradox or Solow paradox.

[ii] First the author also tried to do the analysis with combinations of all three studied innovation activities, but due to the relative smallness of the sample the analysis proved to be not feasible with all three activities together.

[iii] 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.

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

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

[vi] Heckman selection model command cannot be used with panel data. Therefore, the model is estimated with random effects probit model for the selection part of the model and then inverse Mills ratio is calculated from those results. The inverse Mills ratio will be added to the main model as control variable to control for selectivity.

[vii] Due to several difficulties that the selection model has, when using panel data and fixed effect, the author has decided to use OLS model.

KOKKUVÕTE

Tooteinnovatsiooni, turundusinnovatsiooni ja klientidega koostöö komplementaarsus Eesti ettevõtete näitel

Käesolev artikkel uurib koostoimeefekte (komplementaarsuse suhteid) tooteinnovatsiooni, turundusinnovatsiooni ja klientidega koostöö vahel Eesti ettevõtete põhjal. Autor hindab innovatsioonitegevuste vahelist komplementaarust nende mõjuga ettevõtte kogutootlikkusele. Antud artiklis analüüsitakse koos kolme innovatsioonitegevust. Need komplementaarsussuhted ei ole erialakirjanduses tihti kajastust leidnud ja seda eriti tooteinnovatsiooni, turundusinnovatsiooni ja klientidega koostöö vahel. Samuti on töös ühendatud Euroopa innovatsiooniuuringu CIS 2004-2012 perioodi andmed Eesti ettevõtete Äriregistri andmetega, mis andis võimaluse analüüsida täpsemalt ettevõtte tootlikkuse näitajat.

Autor leiab, et tooteinnovatsiooni, turundusinnovatsiooni ja klientidega koostöö vahel ei esine ühtegi universaalset komplementaarsus- või asendusmõju. Lisaks oma positiivsetele omadustele omavad innovatsioonitegevused ka kulusid ettevõtte jaoks ning koostoimeefektid erinevad nii tööstus- ja teenindussektori lõikes kui ka erinevate ajadimensioonide vahel.

Analüüsi tulemused näitavad, et tööstussektoris ei esine komplementaarsusefekti tooteinnovatsiooni ja turundusinnovatsiooni vahel. Seega ei esine tööstusettevõtetes tootinnovatsiooni ja turundusinnovatsiooni vahel lühiajalist sünergiat. Kuid teenindussektoris esineb nende innovatsioonitüüpide vahel komplementaarsusefekt ja tooteinnovatsiooni ning turundusinnovatsiooni koosmõju on suurem, kui nende mõjude summa eraldi. Erinevus tööstussektori tulemustest tuleneb asjaolust, et teenindussektoris on tähtsamal kohal disainimuutused ja turundustegevused (Winter ja Wall, 2006; Stehrer et al., 2014).

Klientidega koostöö ja innovatsioonitüüpide vahel ei esinenud selgeid lühiajalisi koostoimeefekte ei tööstussektoris ega ka teenindussektoris. Kuid tundlikkuse analüüs käigus leiab autor, et klientidega koostöö ja innovatsioonide vahel esineb komplementaarsusefekt, kui uurida koostoimeefekti koondatud paneelandmetega. Kuid komplementaarsusefekt esineb ainult, siis kui ettevõte teeb koostööd klientidega ja seejärel lisa ettevõttesse tooteinnovatsiooni või turundusinnovatsiooni. Vastupidiselt ei esine koostöö klientidega ja innovatsioonide vahel komplementaarsust. Tundlikkuse testi tulemused näitavad, et komplementaarsusefekt klientidega koostöö ja toote- ning turundusinnovatsiooni vahel kasvab ajaga, aga kasv pole siiski piisavalt suur, et väita selget komplementaarsusefekti nende vahel.