Innovation and Firm Performance in a Catching-up Economy

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Abstract

There are a number of studies on the relationship between the innovation and firm performance in the case of highly developed countries, starting with the classic paper by Crépon et al. (1998), however there are only very few studies on the developing countries and similar studies on Central and Eastern European catching-up economies seem to be lacking. This paper studies whether there is significant association between product or process innovation of firms and their productivity in Estonia, a small catching-up economy. We use firm-level data from the Community Innovation Surveys (CIS3 and CIS4) combined with the Estonian Business Register data on the population of all firms and compare the results with similar studies of other European countries. We apply for the analysis a structural model that involves a system of equations on innovation expenditure, innovation outcome and productivity (called in this literature CDM model). Our results show that process innovations have a strong positive effect on productivity, but there is no effect of product innovations.

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1 Introduction

While in the 1990's the research and development has not been linked to recovery and growth in the Central and Eastern European (hereinafter also CEE) countries (Radosevic 2002), we could expect that the sources of economic growth will change and the ability to absorb and develop new products and production processes will become more important for competitiveness. Productivity, measured as the ratio of some output to input (i.e. the sales or value added per worker), is argued to be the crucial variable determining the ability of country to improve its standard of living (Krugman 1990). The low labour productivity compared to the EU average is a legacy of the communist period[2]. As summarized by Stephan (2002), the reasons for the lower productivity in CEE countries include among other reasons lower levels of technology, less developed institutional framework, lower quality of organisational and management expertise and patterns of specialization in international division of labour (less favourable industrial structure of the economy) (Stephan 2002). Kurik et al. (2002) have argued by using the Michael Porter's division of economies into the factor condition based stage, investment driven stage and innovation driven stage that Estonia is in the "investment-driven" stage. Thus the competitive advantage is the cheap production input (mainly labour) and the development of enterprises is largely based on the material (finances and equipment) and immaterial (skills, knowledge, experience) capital accompanying the investments. It seems we may easily extend that conclusion also to most other CEEC countries.

Concerning the impact of innovations of firm performance, the focus could be either on employment, productivity or firm survival. There are a number of studies on the relationship between the innovation and firm performance in the case of highly developed countries, starting with the classic paper by Crépon et al. (1998) (among the other studies we can mention also Griffith et al. 2006, Lööf et al. 2003), however the analogous studies on developing countries seem to be rather scarce and the studies on transition countries seem to almost lacking. One exception is the study buy Damijan et al. (2005) on the innovation processes of Slovenian firms; they found that innovations resulting from the firm's own R&D contributed substantially to firm's total factor productivity growth.

[2] As to the Eurostat, in 2002 the labour productivity was in Estonia in industry and market services 21% of the average of "old" EU (EU15), in Latvia the figure was 21%, in Lithuania 19 % (Eurostat 2004; author's calculations). So all of the three Baltic States lag behind the EU15 countries.

There are a number of characteristic features to the innovative activities of the Estonian firms on which it differs from the international experience. Though the share of innovating firms is not low compared to the EU15 (old members of European Union), the innovation is very much equipment oriented rather than R&D oriented; the innovation cooperation occurs mainly within the value chain (suppliers and clients, customers) and the cooperation with research institutions is limited, service firms are more innovative than the manufacturing firms, both domestic and foreign market oriented firms innovate to the same extent (Kurik et al. 2002; Viia et al. 2007). Currently, the new EU member states like Estonia are losing their traditional sources of international competitiveness like low labour costs that is to large extent connected to their integration into the European Union. In such conditions the ability to innovate has become increasingly important.

For the analysis we use a structural model, often employed for similar studies about effects of innovation in developed countries, that describes the link between R&D expenditure, innovation output, and productivity. This is the Crepon-Duguet-Mairesse model (Crepon et al. 1998). We have used a rich enterprise level panel data – the data from the two Community Innovation Surveys (CIS); these were the CIS-3 data for the 1998-2000 and CIS-4 data for the years 2002-2004. That enables to analyze changes in the innovative activities of firms over time. The CIS data was merged with the Estonian Business Register's firm level data. That database includes the financial information for all Estonian firms for the period of 1995 till 2005. The advantage of using the CIS combined with the latter data is that we can calculate additional productivity measures (like TFP) as well as to study the impact of innovations on productivity over longer time periods. Although the CIS 4 data includes also questions on managerial and marketing innovations, our study, like the previous ones, focuses on technological (product and process) innovations only.

The rest of the paper is structured as follows. Section 2 of our paper gives an overview of the econometric model that we use. Section 3 provides a short summary of the main characteristics of innovative firms in Estonia. Section 4 presents the results of econometric analysis and the last section concludes with policy implications.

2 Econometric Model

Our empirical analysis relies on an adapted version of the commonly used structural model of Crépon, Duguet and Mairesse (Crepon et al., 1998) that has been also called the CDM model. This model explains the productivity of firms by knowledge (innovation output), and innovation output itself by investment into R&D. The usage of CDM model allows us to compare the effects and determinants of innovation in Estonia with findings of several papers using similar approach in the highly developed countries. Similar studies have so far used mostly the CIS-2 and CIS-3 data and have mostly been based on developed countries[3]. Examples include, among others, Crépon et al. 1998, Lööf and Heshmati (2002, 2006), Mairesse and Mohnen (2002, 2005), Lööf et al. 2003, Criscuolo and Haskell (2003), Griffith et al. (2006), and many others. In contrast to previous studies, we estimate the CDM model using CIS-4 data. To our best knowledge, the CDM approach has not been used before for the Central and Eastern European catching-up countries (hereinafter CEECs). Hence, our analysis will give useful new information about the determinants and effects of innovation in the CEECs and a comparison with the results of earlier papers using CIS data of Western European countries. Traditionally, studies using the CDM model have employed data from the manufacturing sector. In order to make findings comparable, we also concentrate here on manufacturing firms. However, for Estonia we have at our disposal data from services sector firms as well.

Next we present the structure of the CDM model we are using in our study. Let us use $i = 1, \dots, N$ to index firms. In principle the CDM approach includes four equations (Crépon et al. 1998):

(1) $g_i^* = \beta_0 x_{0i} + \varepsilon_{0i}$

(2) $k_i^* = \beta_1 x_{1i} + \varepsilon_{1i}$

(3) $t_i^* = \alpha_K k_i^* + \beta_2 x_{2i} + \varepsilon_{2i}$

(4) $q_i = \alpha_T t_i^* + \beta_3 x_{3i} + \varepsilon_{3i}$

Equation (1) models the firm's latent (unobserved) propensity to innovate. The equation (2) links the innovation (R&D) expenditure (the innovation input) intensity to its determinants. Equation (3) is the knowledge production function relating knowledge (innovation output) to

[3] In fact, surveys akin to the CIS have been also conducted, e.g., in China and Chile. Benavente (2006 uses the CDM model to study innovation and firm performance in Chile. For the analysis of the innovation performance

innovation input and other variables. The last equation is the output production function (productivity equation), where innovation output is now used as one of the inputs (Crépon et al. 1998, Lööf et al. 2003). It is assumed in this model that firms use Cobb-Douglas technology with constant returns to scale, using in addition to labour and capital also knowledge inputs (Crépon et al. 1998, Griffith et al. 2006). Note that we are hereby analyzing only cross-section, not panel, data, that is a significant disadvantage given that most of the variables are simultaneously determined (Griffith et al. 2006).

In the CDM model g_i^* is a latent variable that expresses firms' innovation effort that we do not observe in reality. In fact, in our framework all firms engage in some sort of innovation effort/decision, but only a part of them engage in measured R&D (Griffith et al. 2006). We observe the variable k_i^*, innovation input or R&D expenditure, only for firms that have variable g_i^* (effort) larger than some constant threshold (Crépon et al. 1998). Variable t_i^* is innovation output, measured by the process and product innovation dummies (Griffith et al. 2004), or alternatively, as the share of innovative sales in total sales or the sale of new products per employee (Lööf et al. 2003). Variable q_i stands for productivity (sales per employee or value added per employee). The terms x_o, x_1, x_2 and x_3 are vectors of standard inputs to each of the equation, including, depending on equation, proxies for human capital, physical capital, innovation output, industry dummies, firm size, reported obstacles to innovations, sources of innovation, cooperation partners in innovative activities, innovation strategies etc. (Lööf et al. 2003). Parameters of the model are given in vectors b_o, b_1, b_2 and b_3. Vector x_3 includes also physical capital per employee, as we are interested in the effects of innovations on total factor productivity (TFP). List of all variables that are used later in our regression analysis together with their definitions is included in Annex 1.

The four equations are estimated as follows. The two first equations model the two-step innovation decision procedure, because not all firms undertake investment in innovation. In the first step (represented by the first equation) firms decide whether to exercise innovation efforts, and in the 2nd step (represented by equation (2)) the decide about the size of the effort. In the 1st stage the dependent variable is the R&D or innovation expenditure dummy, i.e. a variable that is equal to 1 if firm decides to invest in innovative activities (engage in

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of Chinese companies, see e.g. Jefferson et al. (2003).

R&D) and is 0 if otherwise (Lööf et al. 2003). Equation (2) looks at the size or intensity of the R&D activities (for instance the amount of R&D expenditure per employee). In our study we use instead of R&D expenditure (as used by several other papers) the total expenditure on innovative activities; the reason is the relatively small number of Estonian companies undertaking R&D activities (see also section 3). Concerning the methods for estimating the two equations, Lööf et al. (2003) modelled the first equation as a probit model and the 2nd one as a Tobit model; Griffith et al. (2006) used maximum likelihood estimation of the generalized Tobit model. Here we have used the Heckman 2-step procedure to model the two steps. The explanatory variables used in (1) and (2) (i.e. the vectors x_o and x_1) are partially overlapping in our specification[4].

In the 3-rd step (equation (3) we distinguish between different types of innovation output. As we do not have patent data, and patenting activity of Estonian enterprises is at rather low levels[5], we do not use that type of data (as used, e.g., in Crépon et al. 1998). Instead in the first case we use a dummy variable which is equal to 1 if the firm has introduced some product or process innovation during the studied period (2002-2004). In the second case we measure innovation output as the logarithm of innovation sales per employee and check whether there are important differences between the results of these two alternative specifications. The measures of innovation output are regressed on predicted innovation investments, industry dummies, protection variables, funding variables, sources of information dummies, firm size variable. In our version of the fourth equation, the labour productivity (log of sales or value added per employee[6]) is regressed on innovation output and standard control variables in productivity analysis. Controls will include, among others, the size of the firm (measured as log of employment), export dummy, industry dummies. If the dependent variable in the 3rd step is the process or product innovation dummy, then we have estimated the two knowledge production functions separately as the two probit models; the productivity equation is estimated using the predicted values from the probit model (i.e. we have a instrumental variables regression). If the dependent variable is the innovation sales per employee, then the equations (3) are (4) are similarly estimates as a system of equations with

[4] Sometimes there are small differences between x_o and x_1, e.g., in Griffith et al. (2006).

[5] For instance, in 2003 the number of patents per million of inhabitants was 160.6 in EU15 and 15.5 in Estonia (Eurostat).

[6] We check for the robustness of our results by using also log of value added per employee as the productivity measure.

2-step least squares; a Mills ratio calculated from the Heckman equation is included in the 3-rd step equation in this case.

3 Descriptive Statistics and Overview of the Innovative Activities of Estonian enterprises

We have employed rich enterprise level panel data from the two Community Innovation Surveys (CIS), these were the CIS-3 data for the 1998-2000 and CIS-4 data for the years 2002-2004. The CIS3 data involves 3,161 firms and the CIS 4 data involves 1,747 firms. There are almost 1100 firms that are represented in both surveys. That enables to analyze changes in the innovative activities of firms over time. The CIS data was merged with the Estonian Business Register's firm level data. That database includes the financial information for all Estonian firms for the period of 1995 till 2005. Estonian Business Register's database includes information on the number of employees, sales, valued added, intermediate inputs, thus we can calculate relatively long time series of various productivity variables

The findings of CIS3 and CIS4 in Estonia have been covered thoroughly by, correspondingly, Kurik et al. (2000) and Terk et al. (2007). The main descriptive statistics from the CIS 3 and CIS 4 are presented also in Table 1 and Table 2.

The main findings from the CIS3 were that one-third of the enterprises had innovative activities during 1998–2000. More product- than process-innovation was undertaken. During the following 4 years the share of firms with innovative activities increased considerably in Estonia. The share of firms that had innovative activities in 2002–2004 was according to the CIS4 already 49 per cent. This number is in fact higher than the EU average from the CIS3, which was 44 per cent (Terk et al. 2007).

Table 1 Summary statistics by degree of innovativeness

	CIS 3, 1998-2000		CIS4, 2000-2004	
Sample	**Total**	**Innovative**	**Total**	**Innovative**
Knowledge/innovation				
Product innovation	0.254	0.712	0.379	0.746
Process innovation	0.233	0.654	0.363	0.715
Share of sales with new products	0.082	0.232	0.181	0.181
Innovator	0.333	0.957	0.507	0.981
Continuous R&D engagement	0.100	0.287	0.179	0.347
R&D intensity	122.6	352.3	446.8	864.9
Total innovation expenditure intensity	479.4	1377.3	1713.7	3317.2
Public support				
Local funding	0.004	0.013	0.004	0.008
National funding	0.018	0.051	0.046	0.09
EU funding	0.005	0.015	0.014	0.028
Appropriability conditions				
Formal protection	0.155	0.295	0.15	0.236
Strategic protection	0.251	0.478		
Cooperation	0.125	0.358	0.199	0.385
Other				
Most significant market is international	0.310	0.347	0.703	0.755
Size: 0-19	0.368	0.329	0.318	0.259
Size: 20-49	0.180	0.183	0.273	0.249
Size: 50-99	0.076	0.098	0.156	0.163
Size: 100-249	0.036	0.055	0.118	0.140
Size: 250-999	0.020	0.041	0.036	0.054
Size: >1000	0.003	0.005	0.007	0.009

Note. The numbers reported herein may differ from those reported Kurik et al. (2002) and Terk et al. (2007) because the numbers presented here are calculated without using the sample weights.

Firms that are larger, have foreign ownership or belong to a larger corporate group have more innovative activities than the rest (Ibid. 2007). Whereas in the CIS3 the manufacturing sector firms reported more innovative activities than the services sector ones, in the CIS4 the situation was the other way around. During the 4 years following the CIS3 survey, there has been a large growth in terms of innovativeness of the Estonian services sector. In Estonia especially in manufacturing firms with process innovations have also product innovations, because, for example, the use of a new equipment or machinery generates also an (incremental) product innovation (the characteristics of the existing product are modified as the result of the process innovation).

Table 2 Descriptive statistics of the CIS indicators for Estonian CIS3 and CIS 4 surveys

	CIS 3, 1998-2000		CIS4, 2000-2004	
Sample	**Total**	**Innovative**	**Total**	**Innovative**
Obstacles to innovation: factors of medium or high importance				
Lack of appropriate sources of finance			0.520	0.583
Innovation cost too high	0.464	0.545	0.383	0.465
Lack of qualified personnel	0.318	0.424	0.418	0.519
Lack of information on technology	0.213	0.287	0.216	0.263
Lack of information on markets	0.242	0.305	0.223	0.262
Excessive risk	0.306	0.367		
Organizational rigidities	0.137	0.175		
Rigidity of regulations or standards	0.205	0.249		
Domination of established firms in the market			0.320	0.343
Uncertain demand for innovative products			0.295	0.326
Lack of need due to earlier innovations			0.301	0.185
No demand for innovations			0.313	0.203
Difficulty in finding cooperation partners			0.218	0.255
Innovation impact				
Increased the choice of products or services		0.254		0.357
Enlargement of market or increase of the market share		0.200		0.328
Improved quality of products or services		0.291		0.357
Increased flexibility in production or service provision		0.172		0.215
Reduction of labour costs per unit of production		0.093		0.159
Reduction of material or energy costs per unit of production		0.067		0.121
Reduction of environmental impact		0.075		0.100
Concordance with regulations and standards		0.117		0.164
Increased productivity				0.230
Sources of information: factors of crucial importance				
Sources within the firm or other firms within the group		0.421		0.395
Universities or higher education institutions		0.020		0.038
Suppliers of equipment, materials or software		0.250		0.244
Competitors		0.111		0.111
Customers		0.248		0.264
Consultant enterprises and private R&D firms		0.041		0.048
Fairs, exhibitions		0.097		0.158
Industry associations				0.028
Innovation cooperation				
Other enterprises within the enterprise group		0.143		0.175
Suppliers of equipment, materials or software		0.245		0.272
Customers		0.245		0.258
Competitors		0.154		0.188
Consultant enterprises and private R&D firms		0.156		0.114
Universities or higher education institutions		0.358		0.114
Public R&D institutions		0.358		0.068

Note. The numbers reported herein may differ from those reported Kurik et al. (2002) and Terk et al. (2007) because the numbers presented here are calculated without using the sample weights.

An important difference from Western Europe, that has characterised Estonian economy, has been the very low patenting activity, only 3.2 per cent of firms had applied for patents according to the CIS4. The corresponding average figure from the CIS3 for the EU was 9 per cent[7]. Another difference of Estonia and other CEECs has been the much larger share of spending on machinery and equipment in total innovation expenditures of innovating firms if compared to the Nordic countries or the 'old members' of the EU. At the same time, the share of intramural R&D expenditure is still in CEECs significantly lower than in the Nordic countries (Terk et al. 2007). These findings motivate to model the total investment in innovation activities rather than only the investment in research and development[8].

Compared to old EU member states (EU15), Estonian firms are in relatively close innovation cooperation, about one third of innovative enterprises had cooperation agreements with other enterprises and institutions; however Estonia still lags behind the successful Nordic countries[9] (Kurik et al. 2002); for instance in Finland 44 % and in Sweden 43 % of firms had some kinds of innovation cooperation according to CIS4 (Eurostat). The innovation cooperation relations are mostly within the value chain (suppliers and clients, customers), that is logical given that for many enterprises the most innovative activities are the investments in machinery and equipment. The collaboration especially with universities and enterprises is small, almost three times lower than the average of EU15 (Kurik 2003), and there is no improvement in CIS4 compared to CIS3. The reasons are the large enterprises' low confidence in research establishments as well as that during the fast economic growth it is possible to make profits without seeking for cooperation with research establishments (Innovatiivne tegevus…2007). It will be an important policy issue how to promote the cooperation between firms and research institutions. The cooperation is more inherent to big, exporting enterprises and firms belonging to concerns; it takes mainly place with partners in Estonia or other European countries. Some differences can be observed between manufacturing and services enterprises: in services there is much more innovation cooperation than among manufacturing enterprises (that has been revealed both by CIS3 and CIS4). That refers to that in the services innovations

[7] Similar number for the EU from the CIS4 was not yet available at the time of writing this article.
[8] During 2002-2004, among the innovative firms 73 % had expenditures on the 4 kinds of innovative activities (intramural and extramural R&D, acquisition of knowledge, acquisition of machinery and equipment), however only 35 % had expenditures on intramural R&D. The proportion of those having continuous engagement in intramural R&D is 34 % in the innovative sample (Table 1).
[9] According to CIS3, in EU 66 % of product innovators and 57 % of process innovators the development was carried through within the enterprise itself or within the concern (Terk et al. 2007).

are much more connected to various networks (Terk et al. 2007).

Also the use of different sources of information for innovation differs in Estonia from the highly developed EU member states. Innovation within the enterprise is the main source: approximately every third firm claimed that to be very important (in both surveys). The other main sources for information were suppliers and customers. Outside the business contacts, only fairs and exhibitions are used to a notable extent; the education-related and public research sources were ranked not used very often. There are no major differences between CIS3 and 4. The differences between manufacturing and services enterprises are not big. In case of foreign owned enterprises sources within the enterprise or concern are more important than among domestic enterprises; they were also in closer communication with both suppliers and customers (Terk et al. 2007). Concerning various obstacles to innovation, the most common ones are the lack of appropriate sources of finance (somewhat more the lack within firm or concern, but also the lack of outside firm financing), lack of qualified personnel (that is somewhat less important for the non-innovative firms). Relatively less important reasons are the lack of need due to earlier innovations, knowledge about technology and markets.

The public support to innovations is in Estonia although growing still much lower than in other EU countries. In CIS 3 and 4 respectively 4.9 and 7.9 % of innovative firms had received support from the national sources; only up to 1 % have received any support from local governments. In EU during 1998-2000 about 15 % of enterprises received support from local governments, the same percentage received support from the national government (Terk et al. 2007). For 2002-2004, in the EU-24 the numbers were respectively 6% and 16 % (own calculations from Eurostat data). In case of Estonia opening of the EU structural funds in 2004 has contributed to the increased support towards innovations and R&D.

Concerning the impact of innovative activities, during 2002-2004 manufacturing enterprises showed better results in most categories (Terk et al. 2004). The product oriented impacts (increased choice, improved quality, enlargement of market) were stronger than the process oriented impacts (increased productivity, reduction of labour costs, increased flexibility in production).

In addition to these characteristics, a related paper to ours, by Vahter (2006) that studied the determinants of productivity of Estonian firms, has found that, at least for the period 1996-

2001 there has been low persistence in R&D activities of firms in Estonia. R&D investments used to be to large extent non-continuous. This decreases our expectations about the magnitude of possible positive effects of R&D in our econometric analysis for period 1998-2000. For that reason, we think that it is more appropriate to study the total investment in innovative activities.

Vahter (2006) used also CIS3 data combined with some variables from the Business Register of Estonian firms and documented that there was a statistically significant productivity premium for innovators[10] in year 2000[11]. The productivity premium was found for both unconditional mean comparison of innovators vs non-innovators and also for conditional mean analysis. In the latter case the TFP of firms in 2000 was regressed on dummy variables indicating whether firm had innovations in 1998–2000 or not, and other control variables (such as firm size, Herfindahl index, industry and location dummies).

We next present in Table 3 the descriptive statistics of CIS surveys, incl. unconditional means of labour productivity, wages per employee, capital-to-labour ratio by various types of firm (process innovators, product innovators, firms with R&D expenditure etc.). As we can see, both measures of productivity have on the average higher values in case of innovators compared to non innovators, and that holds across various measures of innovativeness and kinds of innovations. In CIS4, product innovators have slightly higher productivity than process innovators. Differences between capital intensity do not reflect closely the differences in labour productivity as capital intensity is rather high in the class of non-innovators. One possibility is that since in Estonia a rather common type of innovation is investment in new machinery and equipment, firms having made investments in the past may report in survey years both high capital and no innovation (i.e. the innovation obstacle is that the obstacle to innovations is the lack of need due to earlier innovations). However, in surveys firms indicated that to be a relatively unimportant obstacle to innovations. Wages reflect differences between productivities and they are relatively higher especially in case of product innovators. While for 1998-2000 the productivity and wages are the highest for the group of firm with both product and process innovations, then in 2002-2004 these are highest for the firms with only innovations.

[10] I.e., for firms that reported product and/or process innovation in period 1998–2000.
[11] By studying the productivity (incl. the TFP) differences of firms in 2000 according to the fact whether they had innovations in 1998–2000 or not.

Table 3 Labour productivity according to the innovativeness of the firm in 2000 (CIS3) and 2004 (CIS4).

		Sales/employees		Value added/employees		Capital intensity		Wages	
		No	Yes	No	Yes	No	Yes	No	Yes
R&D expenditure	3	434.7	506.6	130.6	168.6	76.7	109.6	48.2	63.2
	4	475.1	595.1	153.9	198.7	127.8	149.9	68.9	85.4
Innovation expenditure	3	438.6	525.9	132.5	178.1	79.1	115	48.6	68.8
	4	483.5	654.5	156.1	225.2	132.7	149.5	69.9	94.3
Process innovation	3	433.9	546.3	133.4	166.9	79.1	112.3	49.3	61.9
	4	475.6	608	157.3	197.3	122.1	164.7	71.6	81.8
Product innovation	3	417.4	584.6	131.6	170.7	83.7	96.4	48.4	64.1
	4	464.2	624.1	155.1	200.4	144.1	125.6	67.9	88.5
Novel product innovation	3	430.4	605.3	134.4	180.4	84.2	92.2	49.7	67.9
	4	486.6	665.8	160.1	215.9	135.9	138.5	71	92.4
Process and product innovation	3	428.0	647.7	134.6	181.1	83.9	104.6	49.7	428
	4	497.9	605.6	162	202.1	137.4	137.1	72.1	497.9

Note. Productivity, capital intensity and wages are for 2004.

We also look at the growth rates of productivity during 1998-2000 and 2002-2004. Terk et al. (2007) noted that while in 1998-2000 innovative firms had significantly higher sales growth than non-innovative firms (respectively 16.9 and 4.4. %), then in 2002-2004 the difference was negligible (respectively 14.4 and 13.0 %), indicating that during the period of fast economic growth[12] it is possible to increase sales without innovations; however the innovativeness mattered for sales growth in manufacturing. The results for the annual productivity growth in Table 4 show somewhat similar pattern. During 1998-2000, the labour productivity growth of innovative firms exceeds that of non-innovative firms both in manufacturing and services. Still in manufacturing the differences between innovation and non-innovative firms are stronger, for instance concerning the firms with process innovations, the differences between the innovative and non-innovative firms productivity growth was 4.5 percentage points in manufacturing and 3.3 percentage points in services (productivity measures as the ratio of sales to employees). In 2002-2004, the differences are not that clear – the sales-to-employees ratio is in manufacturing roughly the same for the four groups of firms; there are still some differences if productivity is measured as the ratio of valued added to employees. The weaker and more non-robust impact of innovations on productivity growth

[12] During 1998-2000 the average rate of GDP growth was in Estonia just % due to the impact of the Russian crises that severely hit the Estonian economy. During 2002-2004, the average rate of economic growth was %.

in the second period might have similar explanations as those we presented above for the varying patterns of productivity growth[13].

Table 4 Annual percentage labour productivity growth according to the innovativeness of the firm in 2000 (CIS3) and 2004 (CIS4).

	CIS	Innovative: no/yes	Sales/employees		Value added / employees	
			Manufacturing	Services	Manufacturing	Services
All firms	3		10.4	4.8	12	6
	4		7.5	13.6	6	13.8
Innovation expenditure	3	No	9.5	4.8	10.3	6.2
	3	Yes	12.5	4.5	16.7	5.5
	4	No	8.2	13	6.9	13.2
	4	Yes	6.4	14.8	4.4	14.8
R&D expenditure	3	No	9.9	4.6	10.4	6.1
	3	Yes	12.5	5.3	19.8	5.8
	4	No	7.4	13.3	6.1	12.7
	4	Yes	7.6	14.8	5.3	17.7
Process innovation	3	No	8.7	3.7	9.7	4.7
	3	Yes	13.2	7	17.3	8.2
	4	No	8.2	13.3	6.2	14.3
	4	Yes	6	14.3	5.5	12.8
Product innovation	3	No	8.5	3.7	9.5	4.4
	3	Yes	13	6.9	16.9	9.0
	4	No	8.2	12.9	6.1	13.3
	4	Yes	6.1	15	5.8	14.9
Novel product innovation	3	No	10	4.7	11.6	5.7
	3	Yes	12.3	4.9	14.3	8.1
	4	No	7.9	13.5	5.7	12.7
	4	Yes	5.6	14.1	7.1	17.6

Note. The productivity growth is measured respectively for CIS3 during 1998-2000 and for CIS4 during 2002-2004.

4 Empirical results

We next continue with the discussion of the parameter estimates of the structural CDM model. The results are presented in tables from Table 5 to Table 7. In the first sub-section we shall present the results of the Tobit model for innovation expenditures, in the 2nd sub-section the probit models for product and process innovations (these are the knowledge production functions) and the last subsection focuses on the results of the estimation of the productivity equation.

[13] The results were roughly the same both when we controlled for the outliers and when we did not do that.

4.1 The Innovation Investment Equations

The results of the generalized Tobit model for innovation investment are presented in the Table 5. First we may note that most of the variables included in both equations (selection equation and outcome equation) are mostly significant in both equations. The most significant market being the international market increases significantly the probability to engage in innovative activities as well as the size of the innovation investment. The usage of the formal protection means increases the probability to engage in innovative activities and the size of innovation investment (that is analogous to the results of Griffith et al. 2006). Similar to previous results are also the impact of funding variables: national funding is more important than EU funding. National funding having a strong positive (and significant) impact on the size of the innovation expenditures could be surprising given its limited size in the period of 2002-2004, however it also seems to imply that the public supports has not strongly crowded out the expenditures by the firms themselves. Local funding variable has not been included in the equations because differently from some other EU countries the local governments in Estonia are mostly rather small and unable to provide any important finances towards R&D. As expected, larger firms are more likely to engage in innovative activities than small firms. The prevailing conclusion from the existing literature is that while the R&D intensity increases with firm size, then the productivity of R&D investments (like the number of innovations relative to the amount of money spent) declines with firm size (Cohen and Klepper 1996).

Table 5 Innovation investment equation

	Engagement in innovative activities	**Innovation investment**
International competition	0.210 (4.83)***	0.566 (4.58)***
Formal protection	0.245 (4.95)***	0.509 (3.32)***
National funding	0.471 (7.5)***	1.462 (5.45)***
EU funding	0.156 (0.61)	0.029 (0.05)
Log number of employees	0.057 (3.54)***	
Innovation cooperation		
Other enterprises within the group		0.006 (0.06)
Suppliers		0.134 (0.97)
Customers		0.039 (0.28)

	Engagement in innovative activities	Innovation investment
Competitors		-0.094
		(-0.88)
Sources of information		
Sources within the firm or other firms within the group		0.146
		(1.98)**
Competitors		0.082
		(0.72)
Customers		0.004
		(0.05)
Suppliers		0.232
		(2.96)***
Obstacles to innovation		
Lack of appropriate sources of finance		-0.143
		(-1.91)*
Innovation cost too high		0.079
		(1.09)
Lack of qualified personnel		-0.069
		(-1.00)
Difficulty in finding cooperation partners		0.026
		(0.32)
Rho		0.369
		(0.151)
Observations	953	953
Log-likelihood		-1291.7

Notes. Absolute values of robust z statistics in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%. Reported are the marginal affects for the probability of engagement in innovative activities and the expected value of innovation investment.

Among the other variables not very many are statistically significant. None of the innovation cooperation variables is significant (aside to those included in the reported regressions, we have also tried different other cooperation partners like universities etc.). That is expected for several cooperation partners that are used to limited extent in Estonian (like universities and R&D institutions), however we might have expected it to be significant in case of suppliers and customers. Also the “difficulty in finding cooperation partners” is not a significant obstacle to innovations that is consistent with these results. Among the different sources of information for innovation, the parameters for suppliers and sources within the firm are significant, that is consistent with our previous knowledge of the Estonian firms’ innovation processes[14]. Concerning the obstacles to innovation, only one, the lack of appropriate sources of finances, is significant. That factor was indicated most often as a factor inhibiting innovations in Estonian CIS[15]. However, all the other factors indicated in the survey more

[14] Ukrainski and Varblane (2006) have analyzed the sources of information for innovation in case of Estonian forest and wood industries.

[15] Some other studies have shown that liquidity constraints (financing constraints) are a significant impediment

often as impediments to innovation (innovation cost too high, difficulty in finding cooperation partners) are insignificant. In case of innovation cost being too high, the impact is unexpectedly positive. The possible explanation could be that in case of more costly innovations also a larger expenditure is needed, so that firms with higher innovation expenditures report the high cost of innovation to be a problem.

4.2 Knowledge production functions (innovation output)

Table 6 presents the regression coefficients of the innovation output equations (knowledge production functions). There are two separate equations, one for product innovations and the other for process innovations; both are estimated as probit models. The predicted innovation expenditure intensity has a positive impact for both the product and process innovations. Thus greater effort per employee implies a higher probability of having any process or product innovations. The protection of innovations through formal methods is more important for product than process innovations; Griffith et al. (2006) obtained a similar result. It could be explained simply by that the protection with formal methods is more often applied to product than process innovations. Firm size has an insignificant impact on product and a positive impact on probability of having process innovations. The variables of the various sources of information for innovations have expected values. Suppliers being an important source for innovation information impacts positively process innovations, customers are important for product innovations, competitors for process innovations. That might show that firms are not able to prevent other firms from obtaining information about their competitive processes and that knowledge spills over to the other firms. As expected, sources within the firm are highly important for both types of innovations (as we saw, that is most often indicates by firms as an important source of innovation information). Sources within the firm or concern have a positive impact on product innovations and negative impact on process innovations; Lööf et al. (2003) found the negative impact for product innovations of Norwegian firms. National innovation funding affects positively product but not process innovations; according to the Estonian CIS4 survey, 9.7% of product and 10.4 % of process innovators declared that they have received any national funding for innovations. The logic for including the funding variables in the knowledge production function is that various subsidies could help the firms to reach more easily from the innovation input to output.

to investments into fixed assets of Estonian firms (Mickiewicz et al. 2004).

Table 6 Knowledge production function – innovation output equations

	Product innovation (0/1)	Process innovation (0/1)
Innovation expenditure	0.166	0.124
	(2.66)***	(1.72)*
Formal protection	0.241	0.082
	(4.16)***	(1.42)
National funding	0.396	0.148
	(4.34)***	(1.29)
EU funding	0.085	0.009
	(0.33)	(0.05)
Log number of employees	-0.017	0.062
	(-0.93)	(3.49)***
Sources within the firm or other firms within the group	0.437	0.185
	(9.18)***	(3.36)***
Competitors	0.059	0.209
	(0.47)	(2.27)**
Customers	0.330	
	(5.49)***	
Suppliers		0.385
		(6.02)***
Observations	951	951
Pseudo-R^2	0.284	0.195
Log-likelihood	-462.0	-514.5

Notes. Absolute values of robust z statistics parentheses * significant at 10%; ** significant at 5%; *** significant at 1%. The t-statistics in parenthesis are robust. The coefficients reported are the marginal effects from the probit model at the sample mean values.

4.3 Output Production Function (Productivity Models)

Table 7 presents the estimates of the output production function (productivity equation); productivity is measured either as the log of the sales or value added per employee. Since the dependent variable is a the natural log of productivity, the presented parameters are the elasticities or semi-elasticities of labour productivity with respect to innovation dummies and other firm-level variables. As expected, capital intensity has a strong positive impact on labour productivity[16]. In both equations, only process innovations have positive significant effect on labour productivity, but not the product innovations. It seems that in earlier studies (Griffith et al. 2006, Lööf et al. 2003) product innovations are found to have somewhat more

[16] Griffith et al. (2006) used in the place of capital intensity the investment intensity due to the lack of the capital variable in their data.

often a significant effect on productivity[17]. The results might imply that during the study period Estonia was still in the stage of economic development where increasing productivity was not achieved thanks to producing products with more value added but by improving the production processes; that is probably also due to many product innovations being relatively incremental not radical. The estimates are quite large: process innovations increase productivity by 12 or 22 % depending on the used measure of productivity (in the sample of Griffith et al. (2006) the values were at most 7 % for process innovations and 18 % for product innovations). The results might imply that during the study period Estonia was still in the stage of economic development where increasing productivity was not achieved thanks to producing products with more value added but by improving the product processes; that is probably also due to many product innovations being relatively incremental not radical. On the other hand, in a catching-up economy there might be relatively many unused possibilities for productivity improvements that are related to both products and processes, thus relatively high rates of return to innovations are normal. In our descriptive tables the differences between innovation and non-innovative firms productivities were respectively 28 and 25 percents in case of process innovations in CIS4 (see Table 3), i.e. only a relatively small part of the differences in descriptive tables can be attributed to other factors. Exporters are found to be more productive than non-exporters. That is a rather usual result in the literature, and that need not to show the impact of exports on productivity but might be caused by that the more productive firms self-select into export markets (Wagner 2007). Productivity is also positively correlated with firm size. The goodness-of-fit can be considered satisfactory given that it is similar to what has been observed in earlier studies in the field.

[17] Griffith et al. (2006) explained that with the problems of measuring the probability like the lack of firm-level price deflators.

Table 7 Output production function (productivity equation)

Dependent variable	Sales/employees	Value added/employees
Capital intensity	0.280	0.196
	(15.00)***	(10.20)***
Product innovation	0.049	0.004
	(1.18)	(0.08)
Process innovation	0.120	0.220
	(1.92)*	(3.21)***
Export dummy	0.223	0.140
	(3.30)***	(2.09)**
Log number of employees	-0.025	-0.067
	(0.95)	(2.41)**
Constant	9.055	9.707
	(12.74)***	(15.27)***
Observations	888	653
R-squared	0.45	0.38

Notes. Reported are coefficients from instrumental variables regression. Absolute values of t statistics in parentheses. Industry dummies are included in all regressions. * significant at 10%; ** significant at 5%; *** significant at 1%.

5 Conclusions and implications

There exists a growing literature on the relationship between innovations and productivity in case of highly developed countries, but there are very few papers on this issue for developing countries and almost no previous studies for the CEEC transition economies (aside to the paper by Damijan et al. 2005). In this paper we have studied the linkage between the innovations and productivity growth in case of Estonia as a small catching-up economy. We have used for this study the CIS 3 and 4 surveys for years 1998-2000 and 2002-2004 respectively. The innovation survey were merged with the Estonian Business Register database. The data was analyzed with the so-called CDM model that has been used to study the relation between innovation and productivity in several papers. The basic structure of our model was as follows: first we estimated the equation for the innovation expenditure intensity, then the knowledge production functions with predicted innovation expenditures from the first step and the 3rd stage we estimated the productivity equation with the predicted innovation output values from the 2nd stage.

The estimated equations performed relatively well and most of the parameter estimates had expected signs. Our results showed that process innovations have a strong positive effect on productivity, but there is no effect of product innovations on productivity. Expectedly, higher innovation expenditure results also in the higher probability that the enterprises produces either product or process innovations. The ability to protect innovations with formal means is more important fro product than process innovations. The dummy for national funding was significant both in the innovation investment intensity equation as well as in the knowledge production functions (probit models). None of the innovation cooperation variables turned out to be statistically significant in the expenditure intensity equation. Various sources of information for innovation mattered for both the intensity of innovation investment as well as for the innovation output: suppliers and competitors are an important source of information for process innovations, customers for product innovations. The size if the innovation investment is affected positively by the presence of R&D supports from national sources.

Our results imply that especially process innovations are a key to the productivity growth in the CEEC catching up economies. The results on the positive effect of government funding on innovation expenditure imply that the funds have been used efficiently in Estonia.

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