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The impact of innovation activities on firm performance using a multi-stage model: Evidence from the Community Innovation Survey 4

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Abstract

The impact of innovation on firm performance has been a matter of significant interest to economists and policy makers for decades. Although innovation is generally regarded as a means of improving the competitiveness of firms and their performance on domestic and foreign markets, this relationship has not been supported unambiguously by empirical work. Innovative activities of firms influence their performance not necessarily directly but through the production of useful innovations and increased productivity. Therefore, in recent years, the relationship between innovation and firm performance has been modelled by a multi-stage approach. However, the findings from existing studies differ in many respects which suggests that there is the need for further research. In this paper we employ firm level data from the fourth Community Innovation Survey (CIS4), covering some 90,000 firms in 16 West and East European countries in order to assess the drivers of the innovation process in two different institutional settings, a number of mature market economies of Western Europe and a number of advanced transition economies from Central and Eastern Europe. A four-equation model, originating in the work of Crepon et al., (1998), has been used to link the innovation decision of firms to their performance through the impact of innovation input on innovation output and the innovation output on productivity and better performance. Our findings confirm the positive relationship between innovation activities and productivity at the firm level and provide further evidence on the relationship between size and innovation activities.

1. Introduction

The traditional economic theory predicts that in the long run all firms will converge to their long run steady state equilibrium position and optimum size. However, the evidence from different industries suggests that firms which perform better today are more likely to perform better tomorrow as well. The main explanation for this non-transitory feature of firm behaviour is the different capabilities of firms to generate and implement new knowledge which determine their relative position in the industry. In last few decades a large number of studies have attempted to map the channels and mechanisms through which new knowledge is transformed into better performance. However, the evidence from this literature is inconclusive thus calling for further research.

The interest in innovation spans from the firm level to the national level. It is argued that countries can achieve higher rates of growth and favourable terms of trade by specialising in knowledge intensive products containing higher added value (OECD/Eurostat 1997). This is the reason why policy makers across the globe have been struggling to develop policies which would stimulate spending on R&D activities and increase the efficiency of the innovation process. In 2000 the EU set itself the goal of becoming the most competitive knowledge based economy in the world. The failure to achieve this goal can be traced to many factors including the inability to stimulate R&D spending and enhance the innovation activities of firms in EU countries, particularly the new members from Central and Eastern European Countries (CEECs) which are seriously lagging behind.

Our study presents one of the first attempts to compare the determinants of the innovation process in mature market economies of Western Europe and the transition economies which have recently joined the EU. A multi-stage approach to innovation is applied to the firm-level data collected by the Fourth Community Innovation Survey (CIS4) in order to identify factors which drive each stage of the innovation process in different institutional settings. The rest of paper is structured as follows. In section 2 we present the theoretical framework for the relationship between innovation and firm performance using a multi-stage framework. Section 3 reviews major findings from the innovation literature. The main characteristics of dataset in our two samples are analysed in section 4 while section 5 presents the methodology and estimative form. The results of our baseline specification are presented in section 6. The sensitivity of the model is examined in section 7. Finally, section 8 concludes.

2. Theoretical framework

Innovation refers to all scientific, technological, organisational, financial and commercial activities which lead to, or are intended to lead to, the implementation of technologically new or improved products or services (OECD/Eurostat, 1997 p. 39). Hence, an innovation contains new ideas which influence the behaviour of economic agents in a previously unknown way. The introduction of new technology, human capital and the improvements in the organisation of production increases firm's efficiency and enables it to produce at lower costs than its rivals. Similarly, the introduction of new products provides consumers with new goods and services which, in turn, lead to the expansion of firms in new segments of the market (OECD/Eurostat, 1997 p. 31). From here it follows that innovations enable firms to differentiate themselves from their rivals (by new products, processes, costs or organisational improvements).

The traditional model of the firm behaviour postulates that innovations can have only transitory effect on firm performance as the new knowledge will soon be diffused and imitated by rivals. Hence, in the long run all firms will converge to the steady-state equilibrium (Knight 1921). However, there is a vast amount of evidence about some firms in different industries and in different institutional settings remaining superior to their rivals for a considerable period of time, irrespective of the measures of firm performance used - employment, sales, productivity or profitability (Klomp and Van Leeuwen 2001, Loof, Heshmati and Asplund, et al. 2002, Kemp, et al. 2003).

The above findings are more consistent with the conceptualisations offered in other schools of thought, particularly Schumpeterian, evolutionist and the endogenous growth theory. According to Schumpeter's thesis of creative destruction, the introduction of new goods, new methods of production, opening of new markets, discovery of new sources of supply and organisational changes are elements within the system which regularly result in the destruction of the existing economic structures and their replacement with new ones. In early Schumpeter's work, the need of active entrepreneurs to constantly move boundaries and to change the existing organisational forms was considered the main generator of innovation (Schumpeter 1934). However, in his later work (Schumpeter 1942), he argued that large firms operating in concentrated industries are the main source of innovative activity. It is suggested that the development of innovation requires the accumulation of knowledge and financial means; thus the small entrepreneur can no longer be the principal driving force of innovation. His role is relegated to large firms and their R & D laboratories which are more likely to posses the necessary human and financial capital. In the Schumpeterian literature, innovation is regarded as a central feature of a market economy.

Another set of explanations are offered by the evolutionary model of the firm (Nelson and Winter 1982) which maintains that the behaviour of any firm consists of, and is based on, a set of learned principles or routines. The quality of individual firm's routines determines its position in relation to rivals, analogous to the position of species in the evolutionary chain. Firms cannot, of course, maintain their superiority permanently on the basis of their existing routines. Innovations, which enable firms to develop new and upgrade existing routines, drive the continuous changes in the economic system.

The endogenous growth literature introduces the simultaneity in the relationship between innovation and performance. In this model the growth of an economy is determined by the level of technology and innovation which, in turn, depend on the share of GDP devoted to these activities (Romer 1990, Grossman and Helpman 1994, Aghion and Howitt 1998). In such setting innovation is seen as a non-rivalrous input in the production process. It is also emphasised that the incentive to innovate is closely linked to the functioning of institutional framework as the innovators would not be able to acquire rents from their invention in an unsuitable institutional environment.

Building on these foundations, Klette et al., (2000) developed the multi-stage model of firm behaviour in which they argue that the growth of a firm is determined by the quality and price of its own and its competitors' products and that the quality of its products can be improved through innovation. The intensity of innovation, however, is postulated to be independent of the firm's size – rather similar to the Gibrat's law. Instead, it is related to the profit margin of firm which, in turn, depends on the degree to which the firm can differentiate its products from its rivals' products. The model also identifies some industry characteristics as the determinants of R&D intensity as the firms in industries with higher demand for high quality products and higher innovative opportunities are more likely to have higher R&D intensity.

In recent years, the above mentioned insights on innovation process have been synthesised in a number of papers through the multi-stage model of innovation process (Crepon, Duguet and Mairesse 1998, Loof and Heshmati 2002, Loof and Heshmati 2006). This stream of literature traces innovation process from firm's decision to innovate to its performance bringing together features of innovation recognised in earlier models such as reverse causality, individual heterogeneity etc. The present paper is based on this approach to modelling the innovation behaviour of firms.

3. Literature review

Studies from the early period of research on innovation have typically reported a positive relationship between innovation and measures of firm performance. Most of these studies used innovation expenditure as the principal measure of innovation at the firm level. Using cross-sectional data for US firms between 1972 and 1977 Griliches (1986) finds that the higher R&D investment leads to higher rates of productivity growth among firms. Basic research appears to be a more important determinant of productivity than other types of R&D and privately financed R&D expenditure appears to be more effective than those financed by the state. These findings were later confirmed by Lichtenberg et al., (1991) who used longitudinal data on US firms between 1972 and 1985. Similar findings have also been reported for other countries. Goto and Suzuki (1989) using a sample of Japanese manufacturing firms in 1982, find that the growth of productivity is positively related to the growth of R&D investment in firm's core activity and also to the growth of R&D investment in supplying industries. Also, Wakelin (1998) find that for a sample of UK firms between 1988 and 1992, R&D intensity had a positive and significant effect on productivity growth.

However, it has been suggested in several studies that R&D expenditure suffers from several shortcomings when used as the measure of innovation activity. The Oslo Manual (OECD/Eurostat, 1997) notes that measures of innovation input, although related to technical change, are not its direct measures. It has also been emphasised that the R&D expenditure does not encompass all innovative efforts of firms such as learning by doing or the knowledge embodied in its investment in new machinery and also its human capital. Kemp et al. (2003) add that studies based on R&D expenditure are not informative on the actual process of innovation. Moreover, the expenditure approach to the innovation may be misleading as the lower amounts of own expenditure on the innovations may simply reflect the fact that the innovation is being developed in cooperation with universities or other firms where the outside agency covers the cost of R&D expenditure. Also, many small firms do not clearly separate R&D investment (or department) from their other activities. Finally, the fact that only a small proportion of the innovation efforts lead to innovation output and better performance means that firms may spend on R&D for many years without reaping the potential benefits of such spending (Bessler and Bittelmeyer 2008).

In a new generation of models studying the impact of innovative activities on firm performance, the focus has shifted to the complex innovation process and channels through which the innovation inputs are transformed into better performance (Crepon, Duguet and

Mairesse 1998, Hall and Kramarz 1998, Loof and Heshmati 2002, Kemp, et al. 2003, Loof and Heshmati 2006, Bessler and Bittelmeyer 2008). In recent years the four-equation model originally developed by Crepon et al. (1998) has become the dominant model within this strand. The model portrays innovation process as consisting of four stages: the decision to innovate, the decision on how much to spend on innovation activities, the relation between expenditure on innovation and innovation output, and the relation between innovation output and performance. These four stages are estimated in a sequential way and it is assumed that the causality runs from the decision to innovate to the firm performance. However, it has also been argued that there is reverse causality from firm performance to innovation output stage. The four stages are modelled in a way to incorporate various factors identified in the literature as determinants of the innovation process such as firm characteristics, industry specific factors and the institutional background. The range of factors used in individual studies depends on the quality and coverage of the dataset used.

The first two stages of the innovation process, i.e. the decision to innovate and the decision on how much to invest in innovation (innovation input) are usually estimated jointly in systemic approach. In the majority of studies, the innovation input is defined as investment in R&D, either as the absolute amount of investment (Loof and Heshmati 2002, Kemp, et al. 2003, Loof and Heshmati 2006) or as the ratio of innovation expenditure to total sales turnover, i.e. innovation intensity (Klomp and Van Leeuwen 2001, Stoevsky 2005, Chudnovsky, Lopez and Pupato 2006). The main advantage of these studies is that they take somewhat broader definition of innovation investment by including expenditures on organisational changes, machinery or marketing in addition to expenditure on R&D.

Most studies have adopted the practice of including same variables as determinants of the decision to innovate and the decision on how much to invest in innovation: the size of the firm, its export intensity, human capital, the possibility of cooperation with customers and research institutions or universities, the existence of public support for innovation, and previous research activity of the firm (Loof and Heshmati 2002, Klomp and Van Leeuwen 2001, Loof and Heshmati 2006). Sometimes the factors which hamper or facilitate innovation such as the access to financing are also included. The evidence from different studies differs in many respects which suggests that there is a need for further investigation of these relationships.

One of the factors frequently related to the decision to innovate and the innovation input is the size of the firm with the number of employees as the most commonly used measure. As noted in section 2, the theory postulates that under different conditions firm size could be positively or negatively related to innovation. This postulate is supported by a large number of empirical studies which have reported positive, negative or even insignificant relationship between the firm's size and its decision to innovate or the innovation input decision (Klomp and Van Leeuwen 2001, Loof and Heshmati 2002, Kemp, et al. 2003, Loof and Heshmati 2006). The main reason for such ambiguous findings may be industry-specific characteristics. As noted by Hall and Kramarz (1998) in industries abundant with low skilled labour, increasing innovation efforts could be the result of the decision of firms to reduce the existing stock of low skill labour and keep only the high skill workers while the opposite may hold for industries with high concentration of skilled labour. Similarly, Acs and Audretsch (1987) find that larger firms are more likely to innovate in industries which are more concentrated and have higher entry barriers while the opposite holds for firms in industries characterised by low entry barriers and higher degree of competition. Finally, Cohen and Klepper (1996) introduce four stylised facts about the relationship between innovation and firm size. First, the probability of a firm undertaking innovation increases with firm size. Second, within an industry, innovation efforts and firm size are positively related across all firm size groups. Third, R&D expenditure rises proportionately with firm size in most industries. Fourth, the number of patents and innovations per unit of innovation investment decreases with firm size.

Another frequently employed determinant of innovation process is export intensity. The previous literature held that higher export intensity facilitates the decision of firms to innovate. The logic behind this thesis is that foreign competition is more intense than domestic and it requires continuous upgrading of the firm's products and processes. Studies for firms in developed countries have reported the existence of a positive relationship between the export intensity and firm's decisions to engage in innovation as well as the amount of investment in innovation (Loof and Heshmati 2002, Kleinknecht and Oostendorp 2002, Kemp, et al. 2003). However, it should be noted that the main trade partners of these countries are other developed countries. While it is true that the export orientation of firms towards the more advanced foreign markets is likely to encourage the decision to innovate, the effect may be non-existent, or even the opposite, when a firm exports to less developed markets. Hence, the direction of relationship between the export intensity and the decision of firm to innovate depends on the character of the foreign market on which they compete.

Another group of factors which are likely to influence the input stage of innovation are the characteristics of socio-economic environment in which the firm operates. These include access to finance, the quality of institutional setting and the country specific cultural values. Various studies have reported that access to finance, particularly the availability of public subsidies for innovation activities, is a crucial determinant of the innovation process (Klomp and Van Leeuwen 2001, Kemp, et al. 2003). The likely reason for this is that in the presence of high levels of uncertainty and information asymmetry (market failures), firms will focus only on those projects which are profitable. Hence, by providing subsidies public authorities motivate firms to undertake also those innovations which would otherwise be abandoned. Apart from subsidies Kemp et al. (2003) find that the innovative input is positively influenced by the contacts and cooperation with research institutes. Finally, Loof et al. (2002) find that the cooperation with domestic rivals, customers and some sources of information is positively related to higher innovative efforts by firms.

An important stage of innovation process is the innovation throughput which encompasses the transformation of innovation inputs into innovation output. In the four-equation model, this stage is modelled through factors which are expected to influence the efficiency of the innovation process such as cooperation with universities and other institutions, or the previous experience in innovation. Besides these, various studies have also included factors which hamper innovative activities such as the financial constraints or the previously abandoned innovations (Klomp and Van Leeuwen 2001, Loof, Heshmati and Asplund, et al. 2002, Kleinknecht and Oostendorp 2002, Kemp, et al. 2003). As with other variables the findings based on different datasets exhibit considerable variations. Klomp and van Leeuwen (2001) report that permanent involvement in R&D has a positive and significant effect on the innovation output while Kemp et al. (2003) add to this also the subsidies and changes in the organisation of firms. The opposite finding is reported by Loof et al., (2002) as in this study none of process related variables is statistically significant determinant of innovation output while the internal sources of information and the objective of extending the product range are significant and positively related to the innovation input. Finally, Klomp et al., (2002) find that interactions between the universities, firms and research institutions have a positive effect on the efficiency of the innovation process.

The innovation output can manifest itself as product and/or process innovations. In the majority of the studies, product innovations are employed as the measure of innovation output and process innovations are neglected (Kemp, et al. 2003). The most commonly employed measures of product innovation are the share of turnover generated by new products, number of patents and new product announcements (Acs and Audretsch 1987, Klomp, et al. 2002, Loof and Heshmati 2002). The proportion of sales attributable to new products is particularly useful as it directly relates the innovation process with the commercial success of firm. The number of patents, on the other hand, is not a very useful measure of innovation output as it presents only an intermediate measure of innovation output and it also suffers from several shortcomings (Kemp, et al. 2003). Finally, there is the new product announcement which measures the innovation output directly (Acs and Audretsch 1987, Kemp, et al. 2003). However, the problem with this measure occurs in cross-country comparisons and the selection of the relevant sources in which new products are announced. Moreover, by confining strictly to this measure it is likely that process innovations remain under-reported. The overall conclusion from the literature is that sales from new products is the most robust measure of innovation output as it includes the entire innovation process (Kemp, et al. 2003).

The determinants of the innovation output have mainly been looked for in the innovation input and process-related variables. Although most studies have hypothesised that the innovation inputs positively influence the innovation output, the empirical evidence has been found only in few cases (Klomp and Van Leeuwen 2001, Loof and Heshmati 2002). Similarly, the relationship between process-related factors and the innovation output has been found only for some factors as we have mentioned earlier in this section. Loof et al., (2002) suggest that these mixed results could be caused by the shortcomings of existing models to properly handle the complexity of the innovation and by the shortcomings of the available datasets. In addition to these determinants, various firm characteristics such as the firm size have been included as the determinants of the innovation output but mostly they have been insignificant (Loof and Heshmati 2002).

The most commonly employed measures of the performance are productivity, sales, export revenues and profits although sometimes financial measures such as the returns on the assets are also employed (Loof and Heshmati 2002, Bessler and Bittelmeyer 2008). Most studies have reported a positive relationship between innovation and firm performance. Loof (2000) tests the existence of a positive relationship between the innovation output measured by sales of new products per employee and five different measures of firm performance (employment growth, value added per employee, sales per employee, operating profit per employee and return on assets). A positive relationship was confirmed for all five indicators. However, not all studies have confirmed the existence of this relationship. Klomp and van Leeuwen (2001), for example, have found a positive relationship between innovation output and sales growth but no evidences of a relationship between the innovation output and employment growth.

Kemp et al. (2003) have found a positive relationship between the innovation output (measured by the share of sales from new products in total turnover) and the growth of turnover and employment and no significant with profit. Bloom and Van Reenen (2002) find that the impact of innovation output on the firm performance appears to be contemporaneous when performance is measured by market value but it occurs with a lag when performance is measured by productivity. Bessler and Bittelmeyer (2008) report that innovations bestow on firms only temporary advantage in the short run and their effect appears to be diminishing in the long run. This finding is consistent with Schumpeterian thesis of creative destruction. Innovations provide competitive advantage for a limited period of time after which knowledge is diffused across the market. As new products enter the market the competitive advantage of the firm diminishes and it will suffer loss and eventually will be forced to exit the market unless it develops even better product.

Loof et al. (2002) find that the innovation output, firm size, and the share of non-R&D engineers and administrators in total employment are significant factors affecting the firm's productivity. Adamou and Sasidsharan (2007) have also found the positive effect of R&D intensity on sales growth. Apart from innovation intensity other significant variables include size and age which have a negative effect on the firm's sales growth Finally, in one of rare studies encompassing both product and process innovations, Nguyen et al., (2007) have found a positive and statistically significant relationship between the different measures of innovation output and export intensity.

Several authors have documented the innovation process in new EU members and some other transition countries as well. Masso and Vahter (2007) find that decisions of Estonian firms to innovate and spending on innovation are positively related with the orientation to international market, existence of formal legal institutions protecting innovations and access to national subsidies. It has been also found that the larger firms have higher propensity to engage in innovative activities while the obstacles to financing are a statistically significant impediment to innovations. In innovation output stage the study distinguishes between the process and product innovations. It is found that the latter is positively related to the protection of innovations and access to subsidies while the former is positively related to the size of the firm. Finally, the performance of firm measured by productivity is positively influenced by process innovations but not by product innovations. The findings for other transition countries are rather similar. Roud (2007) reports results for a sample of Russian firms that the firm's size and the availability of public subsidies positively influence the decision of firms to innovate and the amount of expenditure on innovation while innovation output is influenced by the innovation input and productivity is positively influenced by the innovation output but negatively by the firm's size.

There is much evidence on the benefits which subsidiary firms in developing countries can receive from their mother companies in developed economies. In this context, one may expect to find a difference in the innovation behaviour of domestic and foreign owned companies. Domadenik et al., (2008) find for a sample of Slovenian firms that the firms owned by domestic owners invest significantly more in the R&D than firms owned by other types of owners. However, Chudnovsky et al., (2006) and Stoevsky (2005) do not find any evidence that the innovation efforts are different between domestic and foreign owned companies in Argentina and Bulgaria respectively. Finally, Raffo et al., (2008) conclude that while in general it can be said that foreign owned firms invest more in R&D, the findings on the innovation output and firm performance are very heterogeneous and no general conclusion can be drawn.

4. Data

The empirical analysis in this paper is based on the data from fourth Community Innovation Survey (CIS4), conducted in 2004. This survey covered some 90,000 firms from 16 European countries, including seven which had joined the EU in that year (Czech Republic, Estonia, Hungary, Lithuania, Latvia, Slovenia, Slovakia) and two which were official candidates at that point (Bulgaria and Romania), five EU countries (Spain, France, Italy, Luxembourg and Portugal) and two countries which are not EU members (Iceland and Norway).[1] The surveyed firms are distributed across all major sectors of economic activity.

Table 1 provides descriptive statistics on the innovation behaviour and productivity of firms, grouped according to several criteria, in three groups of countries: total sample, the sub-sample of countries from CEECs and the sub-sample of old EU members together with Norway and Iceland.[2] The comparison of average productivity of firms in different sub-groups across the two sub-samples shows substantial differences, with firms based in old EU group of countries having much higher levels of productivity.

[1] The anonymised data was made available to the Microdyn project on CDROM by Eurostat. Access to the raw data was provided at the Eurostat Safe Centre in Luxembourg. We are grateful to Sergiu-Valentin Parvan for facilitating access to data and confirming the regression results produced at the Centre.
[2] For expositional convenience, hereafter, we will refer to the two groups as Central and East European countries (CEECs) and West European countries.

Table 1: Average productivity of different groups of firms in the database

Sample Criterion	All countries Yes	All countries No	CEECs Yes	CEECs No	Western Europe Yes	Western Europe No
Innovation activity in past 3yrs	211.16	141.05	118.09	81.33	248.71	162.45
Market orientation in past 3 yrs						
Domestic market	186.72	91.31	94.68	56.29	236.79	120.81
EU market	193.33	125.41	84.24	73.43	255.18	161.83
Other foreign markets	239.77	126.84	114.42	71.76	280.67	168.555
Type of cooperation						
Part of a group	338.37	76.04	211.02	49.54	378.38	98.05
Cooperation on innovation activities with other enterprises or institutions in past 3yrs	306.47	161.27	101.72	126.43	408.31	174.96
Factors hampering innovation activities						
Costs	97.88	171.47	44.42	98.70	140.07	213.83
Knowledge	116.58	152.41	49.46	83.40	155.70	198.56
Market factors	110.17	155.22	54.75	83.02	144.01	203.07
Access to subsidies						
Received subsidies from local sources	120.91	208.91	74.41	117.99	123.25	240.89
Received subsidies from national sources	172.02	203.18	92.02	120.17	190.77	230.39
Received subsidies from EU sources	153.29	201.2	58.27	120.28	186.13	226.15

Note: The ‘Yes’ and ‘No’ columns refer to the average productivity of firms with each of the characteristic listed compared with the productivity of firms that do not have that characteristic.
Source: CIS Database, Eurostat

Turning to the most important issue, the difference in performance between innovating and non-innovating firms, it is evident that in both sub–samples, firms undertaking some innovation activities in the three previous years, performed much better than their rivals which did not engage in any innovation activities. However, here again we observe differences among firms in the two groups. Market orientation appears to be another determinant of firm performance. Firms that export to the EU and countries outside the EU, have much higher productivity than firms which sell their products on the domestic market. One explanation for this finding may be that greater competition on the EU and foreign markets forces firms to be more innovative and efficient – but it also reflects the fact that firms withstanding foreign competition are likely to be more efficient in the first place. Other firm characteristics suggest that firms which have some kind of cooperation with rivals, customers, universities or research laboratories and firms which are part of groups have much higher productivity in both sub-samples. This implies that knowledge spillovers play an important role in firm’s performance. With respect to factors hampering innovation, cost obstacles seem to be the most prominent. Firms that reported some kind of obstacle in the innovation process have lower levels of productivity. Contrary to the common wisdom, firms which had access to local, state or EU funded subsidies have much lower levels of productivity.

In summary, it is evident that there are considerable differences in performance, measured by levels of productivity among innovators and non-innovators. Moreover, innovating firms in different sub-samples vary considerably with respect to their performance. This is particularly evident when performance of firms from West European countries is compared with that of firms from CEECs. It appears that apart from innovation, market orientation and creation of networks with other enterprises and research institutions have positive effect on firm's performance while the factors hampering innovation such as cost and knowledge obstacles as well as the use of subsidies are negatively related to the firm performance. The relative weight of these and some additional factors influencing the innovation process and firm performance will be explored in the remainder of this paper.

5. Model specification

The literature on innovation and firm performance identifies two major problems with the econometric specification of this relationship, namely the selectivity bias and simultaneity bias. The selectivity bias arises from the fact that not all firms engage in innovation and some innovations are not successful. In addition, we have already argued that there are many factors which can influence both firms' decision to innovate, its level of expenditure on innovation as well as its final performance. This creates simultaneity bias. The four-stage model discussed earlier (Crepon, Duguet and Mairesse 1998) is capable of addressing these problems. In this model the decision to innovate and the decision on how much to invest in innovation are linked to their determinants in the first two stages of the innovation process. The third stage is a knowledge production function linking innovation input and output. Finally, in the fourth stage the productivity of firm is related to the innovation output.

5.1. General specification of the system model

If g_i^* is unobserved decision variable of whether or not a firm invests in innovation and k_i^* the unobserved level of firm's investment in innovation, with g_i and k_i being their observable counterparts, the first two stages of systemic approach can be defined as follows:

$$g_i = \beta_0 x_i^0 + u_i^0 \qquad (1)$$

$$g_i = 1 \; if \; g_i^* > 0, otherwise \; g_i = 0$$

and

$$k_i | g_i > 0 = \beta_1 x_i^1 + u_i^1 \qquad (2)$$

$$k_i = k_i \ \text{if} \ k_i^* > 0, \text{otherwise} \ k_i = 0$$

In these expressions $x_i^0, x_i^1, \beta_0, \beta_1$ are vectors of independent variables and their corresponding unknown parameters which reflect the impact of certain determinants on the firm's decision to engage in investment in innovation and the actual level of expenditure on innovation. The u_i^0 and u_i^1 are random error terms with zero mean, constant variances and not correlated with the explanatory variables. However, it is assumed that the two error terms are correlated with each other on the basis of unobservable characteristics of firms. In the innovation literature these two stages of the system approach are estimated in two ways. One way of estimation involves a probit equation in the first step and OLS estimation in the second step using inverse Mills ratio from the probit equation to correct for possible selection bias. Alternatively, the first two stages of the systemic approach can be estimated jointly by a generalised tobit model with the maximum likelihood estimation method.

The third stage of the estimation is represented by the following equation:

$$t_i = \alpha_k k_i + \beta_2 x_i^2 + u_i^2 \qquad (3)$$

where t_i represents the observed level of innovation output, k_i and α_k are the innovation input from previous equation and its corresponding unknown parameter, x_i^2 is the vector of other explanatory variables which includes among others inverse Mill's ratio from the first stage and performance from the fourth stage to control for selection bias and feedback effect. β_2 is the vector of corresponding unknown parameters while u_i^2 is the random error term with mean zero and constant variance not correlated with explanatory variables.

Finally, the last equation of the model relates the innovation output with firm's performance.

$$q_i = \alpha_t t_i + \beta_3 x_i^3 + u_i^3 \qquad (4)$$

with q_i indicating firm performance, x_i^3 and β_3 being a vector of independent variables and its corresponding unknown parameters and u_i^3 being the error term. The third and fourth stages are estimated jointly as a system. In the baseline specification we estimate the model with three stage least squares as this methodology allows to control for feedback effect from performance to innovation output stage. However, we also estimate the specification with two stage least squares in which the above mentioned feedback effect is excluded. It is assumed that the error terms are uncorrelated with explanatory variables but the model allows the arbitrary correlation among four error terms which implies that there are some common firm characteristics and unobserved variables influencing all four stages of the innovation process. As a consequence it is possible that innovation input in the third stage and innovation output in fourth are endogenous. This fact is acknowledged and controlled for with proper instrumentation.

5.2. Definition of variables and specification of the model

The four dependent variables of the model and the explanatory variables in each stage are defined as follows.[3] A firm is considered as having taken the decision to innovate if in three years prior to survey, it has undertaken any of the following activities: invested in intramural or extramural activities in R&D, purchased new machinery, equipment and software, purchased or licensed patents, know-how and similar forms of knowledge from other organisations, engaged in training of staff for development of new or significantly improved products or processes and undertook activities for the market introduction of new or significantly improved goods and services. The decision to innovate is modelled as a function of: firm size measured as natural logarithm of employment; three dummy variables for market orientation (national, EU and other); a dummy variable for firm being part of a group; a dummy variable for firms that had in the previous three years ongoing or abandoned innovations; four dummy variables for factors hampering innovation (costs, knowledge, market and other reasons); and two dummy variables for firms that undertook organisational or marketing innovation in previous three years.[4]

Innovation input is indicated by innovation expenditure measured by the natural logarithm of overall amount spent on innovations in 2004. This variable encompasses spending on all innovation activities mentioned above (intramural and extramural R&D expenditure, acquisition of machinery, equipment and software -excluding the machinery, equipment and software for R&D- and other acquisitions of external knowledge).[5] In comparison to selection equation, the innovation input equation includes as explanatory variables also three dummy variables for receiving different types of subsidies (from local, national and EU sources) and four dummy variables for important sources of information on innovation activities (internal sources, market sources, institutional sources and other sources) while market and other

[3] For a fuller definition of variables, see Table A1 in Appendix.
[4] In CIS4 questionairre, the „other factors hampering innovation“ refer to lack of need for innovations due to prior innovations or due to lack of demand for innovations.
[5] This broader definition of innovation input responds to the criticism that many firms (especially smaller ones) would not include R&D expenditure explicitly in their accounts and therefore R&D expenditure would underestimate the actual amounts spend on innovation inputs.

factors hampering innovation are omitted. Hence, we assume that innovative activities of enterprises at this stage are hampered primarily by costs of these activities as well as the knowledge factors such as lack of qualified personnel, lack of information about technology or market.

Innovation output is measured by the natural logarithm of the share of sales of new products and services (new to a firm and new to the firm's market) in total turnover of the firm. The explanatory variables in this equation are: firm size; innovation input from the second stage; inverse mills ratio from the first stage; the natural logarithm of labour productivity; sources of information on innovation activities; organisational and marketing innovations; receiving different types of subsidies; a dummy variable for cooperation with any of suppliers, customers, universities, research laboratories, etc.; and three dummy variables indicating whether the firm perceives its innovation to be highly important for improvement of its products, processes or other aspect of its performance.

The dependent variable in the fourth stage of the model is the natural logarithm of firm's labour productivity defined as the ratio of firm's total turnover by total employment in 2004. It is specified as a function of: firm size; innovation output from third stage; organisational and marketing innovations; factors hampering innovation (all mentioned earlier); two dummy variables for sources of innovation indicating if the improvements in products and processes in the previous three years were developed within enterprise or in the wn efforts cooperation with other firms and institutions. All four models contain three dummy variables for industry specific effects for manufacturing, services and trade sectors.[6] In addition, we include in regressions for full sample a dummy variable for firms located in one of CEECs.

The first two stages include all firms in the sample and are estimated jointly with the maximum likelihood method of generalised tobit. The estimation in third and fourth stage is undertaken on firms that have reported sales from new products. As we already mentioned, these two equations are estimated as a system in a framework of simultaneous equations where the feedback is allowed from productivity to the innovation output. In our baseline specification the last two equations are estimated using three stage least squares system of simultaneous equations.

[6] The base group is 'all other industries'

6. Interpretation of findings

In this section we report the results of the estimation procedure. The analysis was conducted for the full sample and the two sub-samples (Western Europe and CEECs) separately. For expositional convenience the results for each stage of the innovation process will be presented in separate sub-sections.

6.1. Decision to innovate

Table 2 presents the results of the estimation of the first stage for three samples. The results are very similar for the three samples. In general it can be concluded that the probability of engagement in innovation for a typical firm increase with firm size. Firms that are oriented towards national, EU and other foreign markets are more likely to innovate than the firms oriented towards local/regional markets. This implies that the intensity of competition motivates firms to innovate. Being part of the group and having previously abandoned innovation activities also increases the probability of deciding to innovate. This suggests that knowledge accumulated from previous innovative activities (even when they were not successful) as well as knowledge transfer from other parts of group motivates firms to engage in new innovations.

Table 2: Results from the selection equation

	Total	CEECs	WE
Firm size	0.074***	0.077***	0.086***
Market orientation			
National market	0.169***	0.099***	0.189***
EU market	0.142***	-0.003	0.206***
All other countries	0.219***	0.208***	0.182***
Part of a group	0.098***	0.315***	0.025*
Abandoned or ongoing innovations	2.767***	2.870***	2.729***
Highly important factors hampering innovation			
Cost factors	0.086***	0.049**	0.099***
Knowledge factors	0.069***	-0.010	0.098***
Market factors	-0.034***	-0.007	-0.046***
Other reasons for not to innovate	-0.517***	-0.329***	-0.560***
Organisational and marketing innovations			
Organisational innovation	0.782***	0.806***	0.761***
Marketing innovation	0.532***	0.705***	0.462***
Industry specific characteristics			
Manufacturing	0.196***	0.284***	0.178***
Trade	-0.142***	-0.134***	-0.124***
Services	-0.004	0.219***	-0.058***
Institutional setting			
CEECs	0.081	-	=
No. of observations	85777	25527	62244

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively.

A somewhat surprising finding is the positive and significant coefficient on cost and knowledge factors hampering innovation. Loof et al. (2002) report the same finding for Sweden suggesting that an innovating firm has a pool of ideas but the financial and knowledge restrictions force it to be selective, hence selecting only those ideas which have high probability of success. The market factors and other factors hampering innovation (such as the existence of previous innovations) have negative impact on the probability of the firm's decision to engage in innovation activities. Organisational and marketing innovations have a positive impact on the probability of the firm's decision to engage in innovation in all three samples. This suggests that changes in the structure of management, introduction of new skills or improvement of the relations with clients and suppliers as well as design improvements increase the probability of innovation decision.

6.2. Innovation investment

The results from the estimation of the innovation investment equation are presented in Table 3. The findings from all three samples indicate that innovation investment increases with firm size and that the effect of size is similar in all three regressions. Firms oriented towards all markets except the local/regional market invest more in innovation. The only exception is the negative coefficient for the domestic market in the group of new EU countries. One likely explanation is that domestic markets of these countries are not very demanding with respect to knowledge intensive products. Investment in innovation is higher in firms which are part of a group and which previously had abandoned some innovation efforts. In terms of organisational and marketing innovations, the coefficient on organisational innovations is highly significant and positive while the marketing innovations coefficients are negative and only marginally significant in the full sample and in the sub-sample of West European firms (but insignificant for firms in new EU members). A likely explanation for the first two samples could be that marketing innovations and the penetration into new markets involve considerable amount of firm's financial means thus having a negative effect on investment in product and process innovations.

National and EU subsidies have positive and statistically significant effect on the innovation investment in all three regressions. However, local subsidies have negative sign in the full sample and the old EU sample while the coefficient for firms in new EU countries is statistically insignificant. The likely explanation for this is that when deciding on provision of subsidies local administrations may have other objectives and may base their decision on political factors. Another likely explanation could be that the amount of national and EU subsidies is larger and firms must meet stricter criteria to obtain them. Finally, in all three regressions the internal market and institutional sources of information about innovation are statistically significant and positive. The only exception is the group of new EU countries where the coefficient for institutional sources of information is statistically insignificant possibly reflecting insufficient cooperation between firms and universities and other public institutions in these countries. In all three regressions other sources of information (conferences, scientific journals and professional and industry associations) are statistically insignificant.

Table 3: Results from the innovation investment equation

	Total	CEECs	WE
Firm size	0.681***	0.635***	0.693***
Market orientation			
National market	0.814***	-0.082**	1.295***
EU market	0.259***	0.097**	0.219***
All other countries	0.301***	0.282***	0.271***
Part of a group	0.691***	0.532***	0.745***
Abandoned or ongoing innovations	1.051***	0.505***	1.320***
Highly important factors hampering innovation			
Cost factors	0.031	-0.271***	0.134***
Knowledge factors	0.182	-0.064	0.316***
Organisational and marketing innovations			
Organisational innovation	0.116***	0.189***	0.141***
Marketing innovation	-0.090**	-0.021	-0.075*
Access to subsidies			
Local/regional subsidies	-0.356***	0.020	-0.414***
National subsidies	0.863***	0.787***	0.834***
EU subsidies	0.821***	0.562***	0.856***
Highly important sources of information about innovation			
Internal sources	0.886***	0.411***	1.040***
Market sources	0.209***	0.210***	0.225***
Institutional sources	0.514***	-0.045	0.727***
Other sources	-0.018	-0.010	0.076
Industry			
Manufacturing	1.253***	0.171**	1.435***
Trade	1.047***	-0.035	1.224***
Services	1.327***	0.486***	1.444***
Institutional setting			
CEECs	0.974***	-	-
No of observations	85777	25527	62244

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively

6.3. Innovation output

The third stage consists only of firms that have reported positive amount of innovation output. Hence, we include inverse Mill's ratio, calculated from the first equation to control for potential selectivity bias. The results of the estimation are presented in Table 4. The presence of selectivity is indicated only in equation for the full sample and even there the coefficient is only marginally significant, at the 10% level. In the other two cases the coefficient of the Mill's ratio is statistically insignificant.

Table 4: Results from the innovation output equation

	Total	CEECs	WE
Firm size	-0.416***	-0.546***	-0.376***
Mill's ratio	0.211*	0.080	0.187
Innovation input	0.308***	0.621**	0.253***
Productivity	0.065**	-0.552***	0.026
Cooperation	0.158***	0.166***	0.192***
Highly important effects of innovation			
Product effects	0.176***	0.275***	0.182***
Process effects	0.006	0.096***	0.006
Other effects	0.050***	0.146***	0.047**
Organisational and marketing innovations			
Organisational innovation	0.133***	0.047	0.158***
Marketing innovation	0.115***	0.195***	0.068***
Access to subsidies			
Local/regional subsidies	-0.035	-0.063	-0.037
National subsidies	-0.216**	-0.376**	-0.143*
EU subsidies	-0.242***	-0.364*	-0.189**
Highly important sources of information about innovation			
Internal sources	-0.174**	-0.117	-0.159*
Market sources	-0.018	-0.047	-0.003
Institutional sources	-0.082	-0.436	-0.046
Other sources	0.017	0.002	0.038
Industry specific characteristics			
Manufacturing	-0.195	0.056	-0.234
Trade	-0.381***	0.567***	-0.331***
Services	-0.312**	-0.083	-0.302**
Institutional setting			
CEECs	0.225***	-	-
Sample size	15644	5444	10200

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively

The coefficient on firm size is negative and statistically significant in all three regressions. This means, ceteris paribus, a certain amount of innovation investment produces less output in larger firms than in smaller firms (i.e., that larger firms are less efficient than smaller firms in converting innovation input to input output). This finding, and that of the previous sections, appear to confirm the stylised observations put forward by Cohen and Klepper (1996), discussed earlier. In all three regressions we find a positive and statistically significant relationship between innovation input and output. In the full sample an increase of 1% in investment in innovation activities leads to a higher innovation output of about 0.31 percent. In the sub-sample of firms in the new EU countries the effect is even larger and the same increase in innovation investment would yield 0.62 percent increase in the innovation output.[7] The findings with respect to feedback effect from productivity to innovation output are rather ambiguous. While for the full sample we find a positive and statistically significant coefficient, for the sub-sample of firms in CEECs countries the effect of productivity on innovation output is negative and for the sub-sample of West European firms it is insignificant. The finding for CEECs is particularly interesting as it implies that more efficient firms have lower proportion of sales from new products in their total revenues. Having in mind that throughout the transition period firms from these countries largely specialised in labour intensive products produced with standardised technologies, the above finding probably reflects the risk-aversion of their firms. Accordingly, the introduction of new products or services increases the risk of failure which is the reason why these firms transform improvements in efficiency into competitive advantages in production of existing products.

The results from Table 4 include several variables which could be defined as implicit measures of innovation throughput, i.e. the transformation of innovation inputs into innovation output. They indicate that the cooperation with other firms, universities and other institutions influences the innovation output positively. In addition the product oriented effects of innovation such as improvements in quality or the wider range of goods and services are positively correlated with the innovation output. In the case of firms in the new EU countries it is also suggested that the process effects of innovation are also positive and significant. In all three regressions, other effects (that encompass meeting of regulatory requirements and environmental care) are positive and statistically significant.

The two dummy variables for marketing and organisational innovation are statistically significant and positive. This implies that improvements in organisational efficiency and differentiation in terms of design, packaging or delivery help firms to achieve higher sales from new products. With respect to subsidies we find statistically significant coefficients only for the national and EU subsidies, but with negative coefficient. Having in mind the positive effect of these variables on innovation investment, this questions the ability of existing schemes for the allocation of subsidies at both EU and national levels to facilitate innovation process. Among sources of information we find only weak significance for internal sources of information in the full sample and the sample of firms from the old EU countries. In all other cases the sources of information appear to be insignificant.

[7] These coefficients are large but in the Loof, et al.'s work (2001 and 2006) with CIS3, they are also larger (and sometimes larger).

6.4. Productivity (performance) and innovation output

The result of the estimation of the fourth stage of the model is presented in Table 5. The table indicates that the firm's productivity increases significantly with innovation output. In all three regressions the coefficients are statistically significant and positive. The size of the firm also positively and significantly affects its productivity in all three regressions, i.e., that the same level of innovation output has a larger impact on productivity in larger firms than in smaller firms. With respect to the variables indicating sources of innovation we find that firms which develop their product innovation internally or in cooperation with other firms and institutions have higher productivity than firms that implement innovations developed by other firms or institutions. However, with respect to process innovations we find positive coefficients for innovations developed internally and together with other enterprises and institutions for the full sample and for the sub-sample of West European firms but not for the sub-sample of East European firms. For these firms the coefficient for innovations developed within the enterprise is statistically significant and negative. This probably reflects the inability of firms in these countries to undertake process innovations on their own and their dependency on other sources of innovation.

Table 5: Results from the productivity equation

	Total	CEECs	WE
Sample size	15644	5444	10200
Firm size	0.405***	0.178***	0.422***
Innovation output	1.638***	0.644***	1.463***
Source of product innovations			
Within enterprise	0.361***	0.161**	0.760***
Together with other enterprises or institutions	0.113	0.058	0.348***
Sources of process innovations			
Within enterprise	0.693***	-0.280***	1.203***
Together with other enterprises or institutions	0.368***	0.011	0.563***
Organisational and marketing innovations			
Organisational innovation	-0.177***	0.157***	-0.215**
Marketing innovation	-0.099*	-0.075*	0.008
Factors hampering innovation			
Cost factors	-0.156***	-0.398***	-0.111**
Knowledge factors	-0.021	-0.069	0.031
Market factors	0.131***	-0.071	0.240***
Other reasons not to innovate	-0.169**	0.262***	-0.231**
Industry specific characteristics			
Manufacturing	0.111	-0.789***	0.667***
Trade	1.295***	0.516***	1.478***
Services	0.154	-0.368***	0.436***
Institutional setting			
CEECs	-0.637***	-	-

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively

Somewhat puzzling is the negative coefficient on organisational innovations found for the full sample and the sub-sample of firms in Western Europe. The coefficient for marketing innovations is only marginally significant for the full sample and the sub-sample of firms in new EU countries and insignificant for the second sub-sample. The likely explanation is that organizational innovations take some time to be implemented. Therefore, change in organization results in lowering performance of firms in the short run. Finally, among factors hampering innovation we find cost, market and other factors as statistically significant with negative signs. This implies that difficulties of access to external finance, domination of established enterprises and the existence of previous innovations reduce the firm's productivity in the current period.

As a separate group of factors we have also included dummy variables for industry specific effects in all equations of the model. The coefficients are significant in a majority of cases which suggests that there is some degree of individual heterogeneity present. In addition, the coefficient for New EU countries is statistically significant in all but the first stage equation.

7. Sensitivity analysis

To check the sensitivity of above results we exclude feedback effect from the third stage, productivity to innovation output, equation and estimate the system for innovation output and productivity with two-stage least squares method. This method allows only one way causality from the innovation output to productivity. Table 6 presents the results of this estimation. As we can see the results for the main variable of interest, i.e. innovation input, do not differ considerably for the full sample and the sub-sample of West European firms. However, the coefficient on innovation input becomes insignificant in the second sub-sample. With respect to the selection bias coefficient it is now significant in all three regressions suggesting that there are some characteristics which distinguish innovators from non-innovators once we take out the feedback from performance on innovation output. The coefficient on firm size becomes insignificant for the sub-sample of firms in CEECs but it retains the negative sign in all three regressions.

The changes in coefficients are noticeable with respect to other variables as well. In the full sample, the variables for cooperation, other effects of innovation and EU subsidies lose their significance but keep their sign. At the same time, the variables for process effects of innovation, local subsidies, and institutional and other sources of innovation become highly significant. The same findings hold when we restrict our sample to firms in West European countries. In the sub-sample of firms in CEECs, national subsidies lose their significance. In addition, the EU subsidies change their sign from negative to positive while all other variables retain their signs and significance as in previous regressions (Tables 4 and 5).

Table 6: Results from the innovation output equation 2sls

	Total	**CEECs**	**WE**
Sample size	15644	5444	10200
Firm size	-0.391***	-0.096	-0.366***
Innovation input	0.330***	-0.065	0.296***
Mill's ratio	0.427***	-0.131**	0.486***
Cooperation	0.004	0.089***	-0.013
Highly important effects of innovation			
Product effects	0.184***	0.286***	0.114***
Process effects	0.069***	0.068**	0.070***
Other effects	0.026	0.095***	0.008
Organisational and marketing innovations			
Organisational innovation	0.218***	0.042	0.248***
Marketing innovation	0.176***	0.112***	0.147***
Access to subsidies			
Local/regional subsidies	0.219***	0.092	0.224***
National subsidies	-0.185**	0.042	-0.096
EU subsidies	-0.114	0.209***	-0.119
Highly important sources of information about innovation			
Internal sources	-0.309***	0.041	-0.317***
Market sources	-0.053**	-0.001	-0.039
Institutional sources	-0.124**	-0.006	-0.143**
Other sources	0.098***	0.061*	0.078**
Industry specific characteristics			
Manufacturing	-0.129	0.473***	-0.206
Trade	-0.298**	0.217**	-0.322***
Services	-0.261**	0.370***	-0.295**
Institutional setting			
CEECs	0.223***	-	-

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively

Table 7 presents the results for the productivity equation when the feedback effect from productivity to innovation output is excluded. We can see that the new specification does not bring about any major changes with respect to the significance of coefficients or their signs (compare to Table 5). The only exceptions are coefficients for sources of innovation being cooperation with other enterprises or institutions in the full sample, which becomes significant, and the cost factors hampering innovation whose effect in the Western Europe sub-sample diminishes.

In sum, the findings in the productivity equation are unaffected by the exclusion of the feedback effect from productivity to innovation output. However, the findings in the innovation output equation are considerably changed which implies that many variables in this equation are correlated with the excluded variable. These results confirm our expectation about the two-way relationship between firm performance and innovation.

Table 7: Results from the productivity equation 2sls

	Total	**CEECs**	**WE**
Sample size	15644	5444	10200
Firm size	0.403***	0.179***	0.415***
Innovation output	1.632***	0.646***	1.380***
Source of product innovations			
Within enterprise	0.528***	0.156*	0.904***
Together with other enterprises or institutions	0.266**	0.052	0.581***
Sources of process innovations			
Within enterprise	0.534***	-0.301***	1.171***
Together with other enterprises or institutions	0.242**	-0.011	0.509***
Organisational and marketing innovations			
Organisational innovation	-0.176**	0.159***	-0.206**
Marketing innovation	-0.100*	-0.074*	0.006
Factors hampering innovation			
Cost factors	-0.208***	-0.394***	-0.080
Knowledge factors	-0.017	-0.080	0.092
Market factors	0.224***	-0.071	0.372***
Other reasons not to innovate	-0.230**	0.279***	-0.511***
Industry specific characteristics			
Manufacturing	0.106	-0.788***	0.686***
Trade	1.297***	0.516***	1.496***
Services	0.156	-0.367***	0.458***
Institutional setting			
CEECs	-0.634***	-	-

Note: ***, **, * indicate statistical significance at 1%, 5% and 10% levels respectively

8. Conclusion

In recent years the multi-stage approach to the innovation process has become the predominant method for modelling the relationship between innovation and firm performance. It has been suggested that the generation of new knowledge and its transformation to improved performance of firms occur through various stages with different factors affecting different stages of this process. However, the evidence on factors influencing various stages of innovation process differs in many respects, requiring further investigation to clarify these differences. The four stage model, originally developed by Crepon et al. (1998), is capable of capturing the complex nature of the innovation process by highlighting the different stages, from the decision to innovate to the impact of innovation output on firms' productivity. This model makes it possible to take into account the joint inter-dependence of the four stages of the innovation process.

In this paper we employed firm level data from the fourth Community Innovation Survey (CIS4), covering around 90,000 enterprises in 16 European countries, in order to assess the drivers of the innovation process in two different institutional settings, the mature market economies of Western Europe and transition economies from Central and Eastern Europe. In addition, the results for the two groups were compared with those obtained for the full sample.

The empirical results show that investment in innovation activities positively influences the sales of new products. This in turn contributes to the better productivity of firms. The positive feedback effect from productivity to innovation output was found only when firms from all countries are brought together. In mature market economies the feedback is not significant while in case of transition countries we observe negative effect from productivity to innovation output, probably reflecting the strong specialisation of firms from these countries in labour intensive products. However, the exclusion of feedback from the estimation process yields ambiguous results not only with respect to the four stages of innovation process but also with respect to the other variables.

The results for determinants of four stages of innovation process seem to follow general predictions from earlier theoretical and empirical literature on innovation. It was shown that firms engage in innovation and decide how much to invest under the pressure of domestic and international competition (the belief held strongly since the work of Schumpeter). Our evidence indicates that in making this decision firms rely on knowledge accumulated from previously abandoned innovations and use resources from other members of their group or their associates and collaborators. An important conclusion, in comparison with earlier studies, is the confirmation of the relationship between innovation and firm size as put forward by Cohen and Klepper., (1996) . Larger firms are more likely to engage in innovation activities and invest more in innovation but innovation output decreases with firm size.

There is some evidence that the organisational and marketing innovations facilitate successful completion of the innovation process. However, our evidence also indicates that firms in mature market economies implement changes in organisational routines slowly which lead to their lower productivity. It is also evident that high cost of innovation acts as an important obstacle for the decision on how much to spend on innovation in CEECs. The high cost of innovation was also shown to lead to lower productivity of firms in both sub-groups studied. From other factors hampering innovation we find that the lack of knowledge motivates firms to engage in innovation while the existence of established innovations and market structure negatively influence the firm’s decision to innovate and its productivity.

Among the factors facilitating the transformation of innovation input into innovation output national and EU subsidies should be highlighted, particularly as the recipient firms were also found to have lower levels of innovation output. This questions the validity of existing national and EU schemes for subsidizing innovation. Product oriented effects of innovation seem to be another important determinant of the innovation process. In addition, regulatory requirements and environmental issues appear to contribute to higher levels of innovation output. Among the sources of information about innovation we find evidence of significance for internal, institutional and market sources of information in the investment stage of the innovation process. However, at the output stage, only internal sources of information are significant and positive for mature market economies. There is also evidence that, in all samples, the more productive firms undertake product innovations in house. The same finding holds for process innovations but only for firms in mature market economies.

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Appendix

Table A1: Explanation of variables

Dependent variables	
Eq1: Decision to innovate	Dummy variable; 1 if firm in 3 years prior to survey engaged in intramural or extramural R&D, purchased new machinery, equipment, software or other external knowledge, engaged in training of personnel, market research or did any other preparations to implement new or significantly improved products and processes
Eq2: Innovation input (natural logarithm)	Amount (in Euro) of expenditure on intramural or extramural R&D, acquisition of machinery, equipment and software or acquisition of other external knowledge in year of survey.
Eq3: Innovation output (natural logarithm)	Percent of firm's turnover in year of survey coming from goods or services that were new to market or to enterprise in 3 years prior to survey
Eq4: Labour productivity (natural logarithm)	Turnover divided by number of employees in year of survey
Independent variables	
Firm size (natural logarithm)	Number of employees in 2004
National market	Dummy variable; 1 if firm in past 3 years sold goods on national market
EU Market	Dummy variable; 1 if firm in past 3 years sold goods on EU, EFTA or EU candidate countries markets[a]
All other countries	Dummy variable; 1 if firm in past 3 years sold goods on markets of other countries
Part of a group	Dummy variable; 1 if firm is part of an enterprise group
Abandoned or ongoing innovations	Dummy variable; 1 if firm in past 3 years had any abandoned or ongoing innovations
Cost factors	Dummy variable; 1 if firm perceives the lack of funds, finance from sources outside the enterprise and high costs of innovation as highly important factors hampering its innovation activities, projects or decision to innovate
Knowledge factors	Dummy variable; 1 if firm perceives the lack of qualified personnel, information on technology or markets or difficulties in finding cooperation partners for innovation as highly important factors hampering its innovation activities, projects or decision to innovate
Market factors	Dummy variable; 1 if firm perceives the domination over market by established enterprises or the uncertainty of demand for innovation goods and services as highly important factors hampering its innovation activities, projects or decision to innovate
Other reasons not to innovate	Dummy variable; 1 if firm perceives a lack of need to innovate due to prior innovations or low demand for innovations as highly important factors hampering its innovation activities, projects or decision to innovate
Organisational innovation	Dummy variable; 1 if firm in past 3 years introduced new or improved knowledge management system, changed management structure, integrated different activities or introduced changes in its relations with other enterprises or public institutions (alliances, partnerships or subcontracting)
Marketing innovation	Dummy variable; 1 if firm in past 3 years introduced significant changes to packaging of goods or services or changed its sales or distribution methods
Local/regional subsidies	Dummy variable; 1 if firm in past 3 years received financial

Dependent variables	
	support for innovation activities from local/regional authorities
National subsidies	Dummy variable; 1 if firm in past 3 years received financial support for innovation activities from central government
EU subsidies	Dummy variable; 1 if firm in past 3 years received financial support for innovation activities from EU authorities
Internal sources of information about innovation	Dummy variable; 1 if firm perceives sources of information within enterprise or group as highly important
Market sources of information about innovation	Dummy variable; 1 if firm perceives suppliers, customers, competitors, consultants or R&D labs as highly important sources of information on innovation
Institutional sources of information about innovation	Dummy variable; 1 if firm perceives universities or government as highly important sources of information on innovation
Other sources of information about innovation	Dummy variable; 1 if firm perceives conferences, trade fairs, exhibitions, publications, professional and industry associations as highly important sources of information on innovation
Inverse Mill's ratio	Inverse Mill's ratio from selection equation
Product oriented effects of innovation	Dummy variable; 1 if firm perceives increased range of goods and services, increase in market share or improved quality of goods and services as highly important effects of innovations introduced in 3 years prior to survey
Process oriented effects of innovation	Dummy variable; 1 if firm perceives improved flexibility of production, increased capacities, reduced costs of labour, material or energy as highly important effects of innovations introduced in 3 years prior to survey
Other effects of innovation	Dummy variable; 1 if firm perceives reduced environmental impacts, improved health and safety or meeting of regulatory requirements as highly important effects of innovations introduced in 3 years prior to survey
Cooperation	Dummy variable; 1 if firm cooperated on innovations with other enterprises or institutions in 3 years prior to survey
Sources of product innovations	
Within enterprise	Dummy variable; 1 if enterprise developed product innovations in 3 years prior to survey alone (base category: developed by other enterprises or institutions)
In cooperation with other enterprises or institutions	Dummy variable; 1 if enterprise developed product innovations in 3 years prior to survey in cooperation with other enterprises or institutions (base category: developed by other enterprises or institutions)
Sources of process innovations	
Within enterprise	Dummy variable; 1 if enterprise developed process innovations in 3 years prior to survey alone (base category: developed by other enterprises or institutions)
In cooperation with other enterprises or institutions	Dummy variable; 1 if enterprise developed process innovations in 3 years prior to survey in cooperation with other enterprises or institutions (base category: developed by other enterprises or institutions)
Manufacturing	Dummy variable; 1 if firm operates in manufacturing sector (base category: other activities)
Service	Dummy variable; 1 if firm operates in service sector (base category: other activities)
Trade	Dummy variable; 1 if firm operates in trade sector (base category: other activities)
CEECs	Dummy variable; 1 if firm belongs is one of the CEECs (base category: West European countries)

[a] Includes following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden, United Kingdom