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INNOVATION AND PRODUCTIVITY: A FIRM LEVEL STUDY OF UKRAINIAN MANUFACTURING SECTOR

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There is a large literature on innovation contribution to productivity for EU countries including CEE states. At the same time very little is known about CIS countries. We apply the same framework and select the same period (2004-2006) to make our study comparable. The modified CDM model considers not only companies that report formal innovation expenditures but the entire sample of manufacturing firms. This approach accounts for underreporting of innovative firm's efforts, especially among small firms. Additionally, we allow dynamic two-direction relationship between productivity and innovation input and test "success breeds success" hypothesis.

Our major attention is given to the impact of the government support on firm's R&D expenditures, innovations and productivity. The results show that government financial support has positive effect on the probability and amount of firm's innovation expenditures but not on the probability of innovation itself, neither for process nor for product innovation. The latter finding emphasizes that only the effective government innovation policy may actual positively contribute to the productivity after all. We found that both parts of the "success breeds success" hypothesis work. Firms which have introduced new or significantly improved product in the past are more likely to invest into R&D and to come up with a product innovator in the future. Our results also suggest that amount of innovation expenditures in the following period is influenced by firm's productivity in the previous period. Empirical evidence of this is quite rare in the literature. Finally, similar to Estonia during late transition only process innovation has been found to contribute to productivity of Ukrainian firms.

Key words: R&D, innovation, productivity, "success breeds success", transition, Ukraine

JEL code: C33, D24, F14, O31, O33, O47, L60

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INTRODUCTION

Over the period 2000-2008 Ukrainian economy has grown at an average annual rate above 7 percent, mostly due to cheap production inputs such as labor and energy as well as due to high world demand on metallurgical and chemical products. However, as the first Economic Assessment of Ukraine by the Organization for Economic Cooperation and Development (OECD) issued in September, 2007 points out the factors that have boosted such growth are unlikely to last. Indeed, while gains in productivity far outrun wage growth in the first years of the recovery, later wages have been rising rapidly. Cheap gas price is in the past as well. In 2006 it jumped by 90%, in 2007 it increased again by almost 37%, and at the beginning of 2008 we have witnessed its further increase by 38%. Though newly elected president promised to negotiate lower gas prices, they are unlikely to fall as low as in earlier 2000's. The recent crisis has demonstrated very clearly how sensitive to external factor Ukrainian economic growth is. The industrial production declined by 20%, the deepest fall in Europe. It is important for Ukraine to shift to a growth path driven by investments and innovations.

Theoretical models, for instance, endogenous growth theory by Romer (1986), as well as empirical researches (see Griliches and Lichtenberg, 1984; Aghion and Howitt, 1998; Zachariadis, 2003) show that technological changes is the most important contributing factor to economic growth. Few would deny that considerable welfare improvement in the developed countries have been achieved due to innovations. Innovation plays an important role in the competitive process which is to a great extend based upon improved efficiency of production methods, products modification and extension of product lines in order to differentiate yourself from competitors. Additionally, the literature points to a significant spillover effect which is not taken into account by firms in their decision to allocate money to innovations. Number of studies (Griliches, 1992; Griffith, 2000; Bernstein and Nadiri, 1991) has shown that social returns to R&D are higher than private returns across set of industries, which may justify government support to business R&D.

Unfortunately, R&D spending in Ukraine remains substantially lower than in the EU countries. The percentage of government expenditure on R&D in gross domestic product in Ukraine is less than 60%

of the EU25 average, while the ratio for the business R&D expenditure is even worse - only 31% of the EU25 average[2].

Many empirical studies conducted for different countries at the firm level (Crépon et al., 1998; Janz et al., 2003) have demonstrated positive contribution of innovations to productivity. To our knowledge, no such researches have been carried out for Ukraine. Therefore, the aim of this research is to estimate a link between investment in innovations and productivity in Ukrainian manufacturing firms. More precisely, we investigate: 1) the factors that influence both the probability that firm will be engaged in innovative activities and intensity of innovation expenditures; 2) how innovative efforts translate into innovation output; and 3) how innovations eventually influence labor productivity.

These issues are explored applying modified CDM model not only for firms that report having innovation spending but for all firms from our sample. We also analyze how productivity in previous period, measured as sales per employee, affects intensity of innovation spending in current period.

Another purpose of our study is to test "success breeds success" hypothesis suggesting a positive impact of innovative success to further innovations in the following years. This issue is important in terms of practical implication. If innovation is state-dependent, then effective government programs aimed at stimulating innovative activities of enterprises will have a more pronounce effect as they will influence not only the current but the future innovation activities as well.

The structure of this paper is as follows. Literature review is provided in the Part 2. Part 3 outlines the econometric model and the estimation procedure. Part 4 describes our data set. Part 5 reports the main empirical findings and some concluding comments are given in Part 6.

[2] http://www.inco-bruit.eu/English/news3.html

LITERATURE REVIEW

Early empirical studies on innovation are very heterogeneous and hardly comparable. First of all, there was a lack of theoretical model. Secondly, the literature suffered from the disagreement on how to define and measure innovation. Different types of innovation indicators have been developed. Cohen and Klepper (1996) summarize earlier findings.

A large strand of literature on the impact of R&D on firm's productivity and profitability was estimated within a Cobb-Douglas production function framework. Good overview of such studies can be found in Griliches (1995). A serious limitation of this approach as pointed out by Pakes and Griliches (1984) is that it neglects the link labeled as "the knowledge production function". This idea has been further developed by Crépon, Duguet and Mairesse (1998) into a four-equation model, hereafter referred as CDM model, the first of which is selectivity equation and the remaining three are innovation input (R&D), innovation output and firm's productivity equations. It is important to note that CDM model addresses problems which were not taken into account in the previous R&D and patent studies, namely, selectivity and simultaneity biases.

Not all firms are engaged in innovation activities, so they are not randomly selected and if a sample of firms that engage in formal R&D is used for estimation, selectivity bias may arise. Also, there is an issue of the simultaneity in the model, or more specifically endogeneity of innovation input in innovation output equation and endogeneity of innovation output in the productivity equation. The CDM model accounts for simultaneity bias by relying on the instrumental variable approach.

With a sample of French manufacturing enterprises Crépon et al. obtained results which have shown that the firm innovation output, measured as patent numbers or innovative sales, increases with intensity of expenditures on R&D, and that firm's productivity rises with innovation output, even when controlling for physical capital intensity and for the labor skill composition.

Approach introduced by Crépon et al. has been adopted by many other researchers. Empirical literature finds positive correlation between innovation and productivity at the firm level. Estimated elasticity of productivity with respect to innovation output lies between 0.1 and 0.3 (see Lööf et al., 2001). A studies investigating innovation-productivity link has been conducted for developed European countries, among which are those by Lööf and Heshmati (2003) for Norway, Finland and Sweden, Lööf and Heshmati (2002, 2006) for Sweden, Janz et al. (2003) for Germany and Sweden, Griffith et al. (2006) for France, Germany, Spain and UK. These authors have used different versions of the CDM model (Crépon, Duguet and Mairesse, 1998) and relied on data from Community Innovation Surveys (CIS) launched by Eurostat, the statistical office of the European Union. So far four such surveys (CIS 1, CIS 2, CIS 3, CIS 4) have been carried out in 1993-1994, 1996-1997 and 2001-2002, 2002-2004 respectively in every EU member state and associated OECD countries. For all countries mentioned above except Finland the evidence of positive relationship between innovation input and innovation output as well as between innovation output and firm's productivity has been found. It is worth mentioning that in case of Germany diverging results have been obtained. Janz et al. (2003) report positive correlation between productivity and innovation output while Griffith et al. (2006) do not observe any significant relationship among them.

Cross country comparison using firm-level data from the CIS 3 has also been conducted by Griffith et al. (2006) for France, Germany, Spain and UK. In contract to most previous studies, Griffith et al. (2006) made an estimation of the CDM model not only for innovative but for all firms. They motivated their approach by the fact that all firms may undertake some innovative efforts, but they might not be recorded and subsequently reported if they are below some threshold. Another point that makes this paper different to previous studies is that instead of using innovative sales as a measure of innovation output Griffith et al. use dummy variables for product and process innovations indicating whether a firm has introduced new or significantly improved good or production method respectively. They found that in all countries except the UK the ability to protect an innovation through formal or strategic methods is more important for product innovation than for process innovation. Their results also indicate that customers are an important source of information for product innovation, whereas suppliers serve as a determining factor for process innovation. The contributions of process and product innovation to productivity are found to be different. Obtained coefficients of product innovation suggest that on average new or significantly improved product accounts for 17.6% of productivity increase Spain and around 6% – in France and the UK. Process innovation positively influences productivity only in France, accounting for about 7% increase. Coefficients on both product and process innovation are insignificant for Germany.

Investigation of the impact of productivity on firm performance has also been conducted for developing countries (see Benavente, 2006; Chudnovsky et al., 2004; and Raffo, 2007). Benavente (2006) followed the original CDM approach very closely but not all of the obtained results were similar. In line with Crépon et al. (1998) findings, Benavente (2006) shows that larger firms are more likely to undertake R&D, but the intensity of their spending on innovation is not higher relatively to small firms. Also he found that after controlling for sector and firm size, the likelihood of carrying out R&D increases with the degree of market share. But in contrast, neither innovation input has significant impact on innovative sales nor do innovation sales influence productivity. The latter results were somewhat unexpected and inconsistent with previous findings. They have been explained by the substantial lags between introduction of innovation and productivity.

There are few researches which explore relationship between innovation input, innovation output and productivity for transition countries. Masso and Vahter (2008) applied the adopted CDM approach to Estonian manufacturing firms based on the data from CIS 4 (2002-2004). Roud (2007) estimated returns to innovation input and output for Russia in 2005. Findings of both studies overall are in line with those for developed European countries. It seems interesting that, in the case of Estonia only process innovations have significant impact on labor productivity, accounting for 12% of its increase when productivity is measured as sales per employee, and for 22% of its increase when productivity is measured as value added per employee. Meantime, in case of Russia only product innovations positively contribute to productivity. Though, one should keep in mind that periods under consideration slightly differ in these studies and also that different measures of innovative output are used. Masso and Vahter (2008) similar to Griffith et al. (2006) employ indicators of product and process innovation while Roud (2007) similar to Janz et al. (2003) employ innovative sales and a dummy variable for process innovation.

Damijan (2005) tried to replicate results obtained by Crépon et al (1998) using data for Slovenia firms utilizing the same estimation technique. Data cover several years (1996-2002), which allows Damijan to check for the robustness of his results. Author's findings are in agreement with findings of Crépon et al (1998), though direct comparison between them is impossible due to different specifications used. Coefficient of innovation output estimated by Damijan is ten times larger than corresponding coefficient estimated by Crépon et al. However, it should be noted that the former define innovation output as innovation dummy variable while the latter define it as either patents or share of innovative sales.

Different stages of economic development of countries, different country-specific factors influencing innovation processes as well as different estimation methods applied yield variations in estimated impact of innovation on productivity. In addition, there is another issue, which might influence estimation results. All researches presented above except Damijan (2005) utilize cross sectional data. But even Damijan (2005) who relied on panel data, utilized estimation technique used for cross sectional data. However, the modern literature stresses that relationship between R&D and productivity is dynamic. Lööf and Heshmati (2006) emphasize that "capturing this dynamic relationship, which goes in both direction, between R&D and productivity, requires the time aspect to be taken into account. Ideally, one would study how R&D investment in year t-τ influences productivity in year t and how productivity in year t influences the R&D investments in year $t+\tau$. With long time series and detailed lag structure, it may be possible to analyze a recursive equation system with current output depending on past R&D, and with past R&D depending on past rather than current output."

The studies along this line of research that make a use of panel data and the CDM framework are very rare. In fact, we have managed to find only one by Jefferson et al. (2006). The authors analyze firms' innovation behavior and its impact on firm's performance on medium and large Chinese firms. They estimate the CDM model adding an equation for profitability to it. Controlling for lagged R&D intensity, lagged profitability and lagged sales Jefferson et al. (2006) found no correlation between R&D intensity and market concentration. Furthermore, they found significant relationship between R&D investment and new product innovation in Chinese firms and positive contribution of innovative sales to productivity and profitability.

The literature provides several underpinning theoretical arguments for the "success breeds success" hypothesis. This hypothesis assumes that success in innovation has positive impact on further innovation activities and on the innovation success in the following years. For instance, Stoneman (1983) and Mansfield (1968) argued that a firm's success in innovation improves its technological opportunities which make success in innovation more likely in the future (see Peters, 2009). Nelson (1988) showed theoretically that improved technological opportunities increase incentive for enterprises to invest in R&D. Another argument concerns the existence of financial constraints. Innovation projects in general are considered to be quite risky. This according to Stiglitz and Weiss (1981) leads to the moral hazard and adverse selection problems which usually make firms to finance their innovation projects from internal sources. Continuing this line of reasoning Nelson and Winter (1982) added that innovation success results in higher sales, thus providing internal funding for further innovation activities.

The main conclusions that can be drawn from the reviewed literature are the following. Firm's size enhances the chances that a firm will be engaged in innovation activities. At the same time, majority of empirical studies do not find the correlation between firm size and intensity of innovation expenditures. Next, innovation input is positively associated with innovation output. Finally, innovation output has positive effect on labor productivity. However, in the case when innovation output is measured by dummy variables for product and process innovations, contribution of each type to productivity varies across countries. In addition, one would expect firm's innovation success in the past to be a crucial factor determining firm's innovation activity and innovation success in the future.

This study utilize version of CDM approach by Griffith et al. (2006). However, we will introduce several modifications to the model which will allow us to investigate whether productivity and intensity of innovation expenditures in the previous period influence intensity of innovation expenditures in the next period, and whether innovative success in the past has impact on innovation activity and innovative success in the following period.

METHODOLOGY

The estimation strategy employed in the study is based on a modified version of the CDM model developed by Griffith et al. (2006). As mentioned before, in contract to most previous studies the authors estimated the CDM model not only for innovative but for all firms. The model assumes that all firms exercise some innovative efforts but not all firms report them. According to Klomp[3] this assumption has been confirmed by the Statistics of the Netherlands when integrating the R&D and innovation surveys. This issue is also mentioned by Parisi et al. (2006) in their study of Italian manufacturing firms. We believe that this is true for Ukrainian companies as well. Some evidence of underreporting innovation expenditure is observed in our original sample as some firms have reported introducing new or significantly improved product or process in 2006 but have not reported having innovation expenditures either in the current or in the preceding year. This observation might suggest that either time span needed for innovation input to result in innovation output is longer than one year or that these firms undercounted and/or underreported their innovative spending. Thus, we estimate relationship between innovation input, innovation output and productivity for all firms, rather than restricting analysis only to enterprises that are engaged in formal innovation activities.

A structural CDM model, which we apply, consists of four equations and can be interpreted in the following way: First, a firm decides whether to engage in innovation activities or not (equation 1) and how much money to spend (equation 2). Then, innovation inputs are transformed into knowledge or innovation output (equation 3) in a form of product or process innovation, and finally, innovation output influences productivity (equation 4).

Let *i=1, … , N* index firms. Then the model can be formally written as:

$$y_{0i} = \begin{cases} 1 \quad if \; y_{0i}^{*} = \beta_0 X_{0i} + e_{0i} > c \\ 0 \quad if \; y_{0i}^{*} = \beta_0 X_{0i} + e_{0i} \leq c \end{cases} \qquad \textbf{(1)}$$

$$y_{1i} = \beta_1 X_{1i} + \gamma_1 y_{3i,t-1} + \varepsilon_{1i} \qquad if \; y_{0i} = 1 \qquad \textbf{(2)}$$

$$y_{2i} = \gamma_2 \hat{y}_{1i} + \beta_2 X_{2i} + \varepsilon_{2i} \qquad \textbf{(3)}$$

$$y_{3i} = \gamma_3 \hat{y}_{2i} + \beta_3 X_{3i} + \varepsilon_{3i} \qquad \textbf{(4)}$$

[3] http://isi.cbs.nl/iamamember/CD2/pdf/677.PDF

Here, y_{0i} is an observed binary variable equal to 1 for firms with positive reported innovation expenditures, y^*_{0i} is a corresponding unobserved variable such that firms decide to do (and/or report) innovation investments if it is above a certain threshold level *c*, and X_{0i} is a vector of variables explaining the firm's decision to invest resources in innovations. Given that firm *i* decides to invest into R&D and other innovative expenditures, we observe the actual level of these investments y_{1i}. X_{1i} is a vector of the determinants of innovation expenditures, which among other include firm's productivity in the previous year, since the literature (see Lööf and Heshmati, 2006) suggests dynamic two-direction relationship between productivity and innovation input.

Innovation output y_{2i} equation (3) is approximated by two separate measures: product and process innovation, measured as dummy variables. Predicted values of investment in innovation are used among other explanatory variables X_{2i}. Finally, y_{3i} stands for productivity and is measured by the logarithm of sales per employee, and is explained with various variables X_{3i} including the predicted values of innovation output. The β's and γ's are parameters to be estimated, and ε_{0i}, ε_{1i}, ε_{2i} and ε_{3i} are random error terms. Assuming that the error terms ε_{0i} and ε_{1i} in equation (1) and (2) correlate with each other and follow a joint normal distribution with zero mean and constant variances, on the first step, we estimate the first two equations as a generalized Tobit model using the Heckman procedure.

On the second step, knowledge production function (3) is estimated separately for product and process innovation indicators as probit regressions. By using predicted value of innovative expenditures from the estimated generalized Tobit model as an explanatory variable in 3-rd equation, we also instrument innovation expenditures and take care of possible endogeneity of innovative input and innovative output.

On the third step, using OLS we estimate productivity equation, in which we include predicted values from the knowledge production function, and thus take care about endogeneity of innovation output and productivity. Similar to Griffith et al. (2006) we assume a recursive model structure and do not allow the potential feedback effect of productivity on innovation output as it has been done in a some other studies (e.g. Janz et al., 2003; Lööf and Heshmati, 2003; Roud , 2007).

There are several diverging points between our specification of the model and those by Griffith et al. (2006), Lööf et al. (2001) and others which used cross-sectional data for estimation. First, we add the previous period productivity into innovation input equation (equation 2), which enable us to investigate the impact of productivity on the innovation input in the following year. Second, we also include in the equation 2 an indicator of whether firm had expenditures on innovation in previous year, since literature show that R&D expenditures are highly correlated from one year to another (see Griliches, 1998). Third, we directly control for the effect of innovation success in previous years on probability of innovative expenditures and on innovative output in the subsequent year by including indicator for firm's successfulness in producing product innovations in the selection equation (equation 1) and innovation output equation (equation 3). This will allow us to test a well-known "success breeds success" hypothesis.

Before turning to the data description, two comments are worth making at this point, which concern double counting of R&D and a measurement of the innovation input variable. First, in order to avoid the problem of double counting of R&D as innovation costs and by the variable human capital we have subtracted the number of employees working at R&D department from the total number of employees with higher education. As Crépon et al. (1998) emphasize doing so the estimated elasticities of innovation output in the productivity equation do not suffer from R&D double counting biases, and thus should not be given an excess return.

Second, there is a general agreement in the empirical studies relying on cross-sectional data from CIS that the main shortcoming of the innovation input variable is that it is a flow variable and is observed the same year as innovation output. This does not account for the lag between the moments when investment in research is done, actual product innovation happened, and market acceptance of the new product occurred. Griliches (1998) reports some weak evidence that such lags are rather short (see Janz et al., 2003). Unfortunately, we cannot make an advantage of our panel data (2004-2006) with respect to innovation input variable due to the following data limitation. In order to use innovation input in 2005 as explanatory variable for innovation output in 2006, we would have to estimate predicted innovation expenditure in 2005, but our data do not contain some important variables for year 2004. The latter imply that we would receive not very good predictions. Thus, we are forced to ignore possible lags as well. List of all variables employed in the study and their definitions are presented in Table 1.

DATA DESCRIPTION

The dataset used in this study is enterprise level data for manufacturing sector (NACE 10-41) collected by the State Statistics Committee of Ukraine (Derzhkomstat) on an annual basis in 2004-2006. It is based on information taken from the following forms: #2 – income statement, #1 – entrepreneurship, #6pv – employment and wages statement, #1 – innovation. The dataset on the annual income statement for all manufacturing companies in 2004-2006 was merged with other datasets which include information on firms' innovative activities, sales, human capital, five-digit industry code, investment in physical capital, whether the firm has merged with another enterprise, and whether part of a firm has been sold as well as whether a firm has been establish during 2004-2006. Two-digit industry production price index is used to deflate sales, innovation expenditures, investment, and all other variables measured in nominal terms.

In a process of sample construction, first, we generated a list of all firms that reported the manufacturing industry code (NACE 10-41) any time during 2004-2006, including non-operating firms. From this list we randomly draw 2000 firms. Then, we excluded all firms which in 2006 either did not operate or which main activity laid outside the manufacturing sector. This leaves us 933 firms. We also dropped 141 firms which did not operate in 2004 or 2005 years unless they are newly-established. Another 9 firms reported out-of-manufacturing industry codes in 2004-2005 and have been excluded too. Finally, we obtained a sample of 783 firms. We would like to draw reader's attention that this 60% reduction of the original sample is not an outcome of some restrictive procedure but a consequence of the very dirty registry[4]. Other researches in the field faced the issue of incomplete information in the original data set. For instance, in the study by Lööf and Heshmati (2002) the number of firms after eliminating those with missing units of information has dropped by almost 50%, from 6222 to 3190.

[4] Firm's distribution with respect to industrial affiliation in the original dataset closely mimics the estimation sample, presented in Table B in the Appendix. Average firm sales in the original sample are 70.8 bln. UAH , average employment – 320 workers. Both are very comparable to the parameters of the estimation sample.

Definitions of an innovative firm that is used in empirical studies differ depending on a model specification applied. For instance, Janz et al. (2003) consider a company as innovative if additionally to introducing a new or significantly improved product in the market, it has positive innovation expenditure. Lööf and Heshmati (2002) define an innovative firm as a firm with both positive innovation investment and positive innovative sales. We define an innovative firm as a firm that have introduced at least one product innovation to the market or implemented at least one process innovation during a considered year, accordingly, a non-innovative firm is a firm that has introduced neither innovation product nor implemented innovation process. In an annual digest covering different aspects of innovation activity, the Ukrainian Statistics Committee in particular reports statistics on the number and percentage of firms that implemented innovations over the reviewed year. Those firms include firms that implemented process innovations, firms that implemented product innovations and firms that had acquired machines, equipment or other fixed assets related to implementation of innovations during a year. We will compare our sample with official figures.

Summary statistics for total sample are reported in Table 2. They reveal that there are about 14.4% of all enterprises in our sample that can be classified as a firm that implemented innovations according to the Derzhkomstat definition. Moreover, 9.6% of them can be considered as such that implemented innovations continuously over the period of 2004-2006. Percentage of product innovators is a bit higher than process innovators, 9.8% and 6.3% respectively. About 4% of all firms have reported both process and product innovations. These numbers are slightly above the officially reported statistics but follow a similar distribution.

The average enterprise employed about 331 people, 18.4% of which had higher education. On average firm's sales amount to UAH 66 mln (~9.4 mnl Euro), 3.3% of which were sales derived from innovative products. Average investments in innovation activities comprises about 1.1% of total sales; meanwhile share of gross investment in tangible assets was considerably higher and comprised 9.8%. About 6% of all firms have conducted their own research and development. Moreover, 3.7% of firms did it on a continuous basis, which means they reported positive expenditure on R&D each year during the period considered. But only 2.3% of all enterprises have acquired new technology. Though, our data do not contain information on the date of establishment for all firms, we can say that the majority of firms have come into existence before 2004. Only 21 firms or 2.7% of the entire sample have appeared in 2004-2006. The share of firms which revenue in 2006 has decreased by 10% or more due to sales or closure of part of the firm during 2004-2006 comprised 3.8%.

The most important market for a firm is defined as a market where firm's sales were the highest. We can distinguish between three markets on which company operates: market within Ukraine, market of CIS countries, and market of other countries. If the amount of sales received at domestic market is equal to the export we consider that a firm's most important market is foreign. In case of equal sales earned at the market of CIS countries and on the market of other countries we consider the latter as the most important for a firm. Summary statistics show that the majority of enterprises (93.2%) in our sample are focused on the Ukrainian market, whereas only 2% of enterprises mostly operate on the market of CIS countries, and 4.8% – on the market of other countries.

The level of government funding to innovation activities of Ukrainian companies is very low. The level of government R&D expenditures declined to less than 1% of GDP in 2006[5]. Only 1.1% of all firms in our sample have received financial support for innovation activities from the local or state budgets.

Turning to summary statistics of innovative and non-innovative firms, which can be found in Table 3, it is interesting to notice that almost 30% of innovative sample are firms that have implemented both process and product innovations. Comparing innovative firms and their non-innovative counterparts, we see that on average innovative firms are larger, have higher percentage of employees with higher education and higher level of employment in R&D department. Moreover, innovative enterprises have slightly larger sales per employee and are more oriented on the market abroad in comparison with non-innovative companies but still for the majority of both types of firms the market within Ukraine dominates. As it might be expected, innovative firms invest more in innovations which include R&D, acquisition of new machines, equipment, technologies etc., and get much higher level of innovation output. We do not observe the same tendency with respect to investment in fixed tangible assets, since share of physical capital investment to total amount of sales for innovative companies is 9.2% which is quite similar to that for non-innovative companies 9.9%.

[5] INNO-Policy TrendChart - Policy Trends and Appraisal Report, 2007

It is interesting to notice that the number of newly established companies is almost the same in innovative and non-innovative sub-samples, about 2.6% and 3% respectively. Further, the number of enterprises which sales in 2006 have decreased by 10% or more due to sales or closure of part of the firm during 2004-2006 is slightly higher among non-innovative firms. Innovation activities of almost 4% of innovative enterprises in Ukraine were subsidized by the government in 2004-2006, which is much lower in comparison with in EU countries. Meantime, Masso and Vahter (2008) report that about 15% of firms received financial support from local authorities and the same share of firms received financial support from the national government in Estonia.

EMPIRICAL RESULTS

Selection equation

We start our discussion of the estimation results from the selection equation. As the first column of Table 4 reveals, the probability of innovation investments increases with a firm size. This is most likely due to the scale effect, which means that for large enterprises it is easier to raise enough funds for substantial innovation expenditures. Also large firms have better opportunities to diversify the risk related to innovation activities since they can distribute fixed cost associated with innovation investments over larger sales volume. This finding is consistent with stylized facts by Cohen and Klepper (1996). Coefficient of market concentration is insignificant. Furthermore, firm's current decision on whether to engage in innovation activities is largely determined by its previous success in introduction of either product or process innovations to the market in a prior period. This direct, thus more appropriate, indicator of previous innovative success provides a strong evidence for the first part of "success breeds success" hypothesis suggesting that innovation success positively correlates with further innovation activities.

Moreover, our result indicates that government financial support is the most important driver of firms' decision to allocate its resources in innovative activity. The same result was obtained by some other researchers (see Griffith et al., 2006; Masso and Vahter, 2008; Damijan, 2005). On the other hand, in contrast to the findings of Janz et al. (2003) for Germany and Sweden, which suggest that firms that operate on international market are more likely to have innovation expenditures, we do not observe significance of this factor for Ukrainian firms. Finally, being a newly established company has a positive effect on the decision on undertaking innovation efforts while no impact is found due to decrease in output associated with leasing or sale of assets or closure of a part of the firm.

Innovation input equation

Several interesting results are found when estimating innovation input equation (equation 2). Although we have observe that larger firms are more likely to engage in innovation activities, intensity of innovation input does not seem to correlate with firm size (see Table 4, second column). This finding is in line with stylized facts by Cohen and Klepper (1996). As we expected, innovation expenditures in previous year positively and highly correlate with innovation expenditures in the current year. Impact of government financial support on the investment intensity is positive, which implies that government subsidies do not have crowding out firms innovation expenditures. The literature in general is inconclusive concerning the impact of R&D subsidies. Griffith et al. (2006), Peters (2009) and Masso and Vahter (2008) reported positive effect of government funding. In a case of Russia Roud (2007) also found that government support greatly stimulates firms to increase their innovation expenditure. Meanwhile Wallsten (2000) showed that technologically intensive US firms reduced their R&D expenditure in the years following the receiving of R&D subsidies, whereas Janz et al. (2003) have not found any significant effect at all.

Another interesting finding is a positive and significant coefficient of the previous year productivity. It confirms the existence of impact of productivity on innovation input in the following period. This issue is discussed in the modern literature but empirical evidences are rare due to prevailing usage of cross-sectional data.

As it is expected, we found that firms with a larger share of more educated personnel invest relatively more into R&D. Additionally, that firms exporting to CIS countries report higher intensity of resources allocated to innovation. We also observe that decline in sales due to the enterprise's downsizing contributes to a higher intensity.

Innovation output equation

Table 5 presents the estimates of the innovation output equation (equation 3) for product innovation (column 1) and for process innovation (column 2), both being measured as dummy variables. The amount of innovation expenditures has a significant impact on the probability of both product and process innovation. Griffith et al. (2006) and Masso and Vahter (2008), who define innovation output in the same way, obtained similar results. Other empirical studies that restricted analyses only to innovative firms also found that innovation expenditures contribute to innovation output (e.g. Janz et al., 2003; Janz and Peters, 2002; Lööf and Heshmati, 2002). As expected and in accordance with other empirical findings the probability of being a product innovator as well as a process innovator increases with firm size.

We have found that previous innovative success, indicating that an enterprise has introduced product innovation in the past, is an important factor that influences probability of product innovation in the following periods. Thus, our finding support the second part of hypothesis "success breeds success". However, we do not observe association between previous success in product innovation and current success in process innovation. As it was mentioned before data do not allow us examine impact of firms' successfulness in implementing process innovations in the past on current innovations.

Obtained estimates make it clear that firm's orientation on market of CIS counties and a decrease in sales by 10% or more due to sales or closure of part of the firm during 2004-2006 largely reduce probability of both product and process innovations. At the same time, whether a firm is newly established or not does not matter. Surprisingly, investment in physical capital has no impact on process innovation whereas Griffith et al. (2006) report positive and significant relationship for all four countries that their research covers. However, Janz et al. (2003) also have found significant effect of innovation investment on innovation output neither in pooled nor separate regressions for Sweden and Germany.

Another important finding here is a lack of any significant impact of government funding on innovation output both for product and process innovation output. We included government funding variable in the innovation output equation given its large impact on the innovation input (both probability and intensity). Indeed, it is possible to argue that subsidies can be used to facilitate the process of transformation of innovation input to innovation output. However, we have not received evidence of this.

Productivity equation

The empirical results for productivity equation are reported in the third column of Table 5. As one would expect, productivity is an increasing function of firm size and human capital, which is consistent with previous findings of the studies in this line of research. Unsurprisingly, physical capital investment correlates with labor productivity and on average associated with 22.5% increase in productivity.

Only coefficient on process innovation is found to be significant indicating contribution of process innovation to productivity. Meanwhile, product innovation does not have statistically significant impact on productivity. Several possible explanations of these results can be provided. It might be that, given the rapid growth of wages, enterprises implemented new or significantly improved production methods in order to reduced costs. On the other side, this finding may be demand driven, i.e. enterprises change technological processes in order to meet growing demand. Potentially such result may reflect particularities of the industry development level, when firms prefer to import more innovative products while investing into the technological process. Alternatively, it might be that more time is needed for innovation investment to be transformed into innovation product, and then for innovation product to impact productivity. It is worth mentioning that Masso and Vahter (2008) obtained the same result using data from CIS 4 for Estonian firms.

SUMMARY AND CONCLUSIONS

Most of the existing empirical studies on innovation activities are conducted for advanced economies. The role of technological change in developing and transition countries, however, might differ substantially. With the enlargement of the European economic area it becomes imperative to learn more about the innovation activities in candidate and neighbouring countries in order to foster the innovation capacity of all countries. This paper presents one of the first empirical studies for the Ukrainian economy. We apply CDM model using data set of 783 Ukrainian manufacturing firms in the period between 2004 and 2006. The paper has four sets of results. First, we have investigated factors determining firm's choice to invest resources in innovation activities. Second, we have explored determinants of intensity of innovation expenditures. Third, we have evaluated the contribution of innovation output to labor productivity. Finally, we have tested the "success breeds success" hypothesis suggesting a positive impact of innovative success on further innovations in the following years.

The provided analysis of the mechanism driving innovation and firm's productivity reveals the following. Among main determinants of the probability that firm will undertake innovation efforts are firm size, government funding and firm's age. We have not found any significant effect of market concentration, human capital or the most important firm's market on the likelihood to invest in innovation. Our results also suggest that firms with positive experience in producing innovation are more likely to spend again on innovation. This finding confirms the first part of "success breeds success" hypothesis.

The intensity of innovation expenditures does not depend on the firm size, given that the firm decides to invest. But investment intensity in the previous periods and government support in the current period are found to be crucial. The former finding suggests that R&D expenditures are correlated from one year to another. The latter finding suggests that government funding induce firms to invest more in innovation activities. Therefore, state support does not cause crowding out effect on the innovation expenditure by the firms. Nevertheless, one should be careful arguing for large government support here given that no impact of this factor on the innovation output is found. This may imply that government money is spent inefficiently. Another possible explanation involves a certain selection mechanism behind the R&D subsidy distribution.

An interesting result from our point of view is that productivity in previous period indeed has positive impact on current investment intensity. This endogeneity issue is discussed in the literature but empirical verification is rather none. Thus, this paper provides an evidence of two-way relationship between innovation input and productivity. Not only innovation input through innovation output influences productivity but also more productive firms aim to maintain their advantage with higher R&D expenditure in the subsequent period.

Innovation input and firm size are important factors influencing the probabilities of product innovation and process innovation. Moreover, large firms and firms that were successful in introducing product innovations in the previous periods are more likely to become product innovator in the current period. This confirms the second part of "success breeds success" hypothesis. So, success indeed breeds success.

Process innovation is found to be among important contributors to productivity. No such association has been found in a case of product innovation. This result resembles findings of Masso and Vahter (2008) for Estonia in 2002-2004 (CIS4). Contrary, in earlier periods (CIS3, 1998-2000) firms contributed to productivity either more or exclusively through product innovation (Masso and Vahter, 2008; Grifith et al., 2006; Lööf et al. 2003). These results potentially suggest that rising labor costs and price competition during late transition call firms to cannel their productivity improvement through new or significantly improved production methods rather than through broader product portfolio. Alternatively, it might imply that more than one year is needed in order to undertaken innovation efforts result in product innovation and then product innovation influences productivity.

We would like to conclude our study with the following policy implications. Given rapidly aging Ukrainian population, one of the challenges for government is to increase productivity. So, productivity growth should be a key issue on the policy agenda. Provided analysis indicates an importance of innovations for productivity. At the same time, long argued government involvement does not result into innovation output. Hence, direct measures are unlikely to help and efforts should be directed to creating institutions and environment that stimulates innovation activities of enterprises. The Law on Scientific and Technological Activities set target of 1.7% of GDP to be devoted to R&D financing from the state budget, but in 2006 the level of government R&D expenditures declined to less than 1% of GDP. After this financial crisis sustainable growth becomes even a more important issue.

Thus, real incentives for firms to increase their innovation expenditures are to be introduced by policy makers. Results of our research show that government financial finding is a crucial factor influencing firm's decision to undertake innovative efforts and also it stimulates firms to increase their innovation expenditures. Unfortunately, this does not translate into actual innovations. Therefore, it is important to distribute government finances though competitive procedures to ensure the efficiency of such procedure.

Firm's past innovation success has positive and significant impact on its further innovation activities and innovation success in the following periods. Also firm's productivity positively influences intensity of innovation investments in the subsequent year. These imply that programs aimed at stimulating firms' innovation activities will have long lasting effect, since they affect both current and future innovation activities.

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APPENDIX

Table A: Industries aggregation

Aggregated industry	Industry	NACE code
Industry 1	Mining / Quarrying	10-14
	Food / Tobacco	15, 16
Industry 2	Textiles / Leather	17-19
Industry 3	Wood / Paper/ Printing	20-22
Industry 4	Chemicals / Coke	23, 24
	Rubber / Plastic	25
	Glass / Ceramics	26
	Metals	27, 28
Industry 5	Machinery	29
Industry 6	Electrical engineering	30-32
	Medical instruments	33
	Transport equipment	34, 35
Industry 7	Furniture / Recycling	36, 37
	Electricity, gas and water supply	40, 41

Table B: Sample by industries

Industry	NACE code	Total sample		Innovative sample[a]	
		number	%	number	%
Mining / Quarrying	10-14	42	5.42	2	2.02
Food / Tobacco	15, 16	229	28.88	25	25.25
Textiles / Leather	17-19	60	7.57	3	3.03
Wood / Paper/ Printing	20-22	57	7.19	4	4.04
Chemicals / Coke	23, 24	36	4.54	11	11.11
Rubber / Plastic	25	23	2.90	2	2.02
Glass / Ceramics	26	67	8.45	3	3.03
Metals	27, 28	57	7.19	11	11.11
Machinery	29	82	10.34	21	21.21
Electrical engineering	30-32	28	3.53	5	5.05
Medical instruments	33	13	1.64	6	6.06
Transport equipment	34, 35	19	2.40	3	3.03
Furniture / Recycling	36, 37	23	2.90	1	1.01
Electricity, gas and water supply	40, 41	56	7.06	2	2.02
Total		792	100	99	100

a) Innovative sample includes firms with product or process innovations

Table 1: Variable definitions

VARIABLE	DEFINITION
Quantitative variables	
Firm size	Number of employees in 2006 (in log)
Innovation input	Expenditure related to innovations in 2006, per employee (in log)
Innovation output	Sales income from product innovations in 2006, per employee (in log)
Physical capital investment	Gross investment in tangible goods per employee in 2006 (in log)
Productivity	Sales per employee in 2006 (in log)
Productivity_2005	Sales per employee in 2005 (in log)
Qualitative variables	
Human capital	Share of employees with higher education
Product innovation	Dummy variable being 1 if the firm that introduced new or significantly improved product on the market
Process innovation	Dummy variable being 1 if the firm that used within a production a new technological process
Innovation expenditure_2005	Dummy variable being 1 if the firm had positive innovation investment in 2005
Previous success	Dummy variable being 1 if the firm had positive sales revenue received from product innovations in any year between 2004-2005
Newly established	Dummy variable being 1 if the firm has been established during 2004-2006
Downsized	Dummy variable being 1 if firm's sales decreased 10% or more due to sales or closure of part of firm during 2004-2006
Government funding	Dummy variable being 1 if the firm receive any financial support from state or local budget for innovation activities between 2004-2006
Market concentration	Herfindahl-Hirshman index for 2005
Most important market:	
Local market	Dummy variable being 1 if the firm receive the largest sales revenue on market within Ukraine in 2006
CIS countries	Dummy variable being 1 if the firm receive the largest sales revenue from exporting to CIS countries in 2006
Other countries	Dummy variable being 1 if the firm receive the largest sales revenue from exporting to other countries in 2006

Table 2: Summary statistics for total sample in 2006

Variable	Mean	Std. Dev.	Min	Max
Quantitative variables				
Sales in 1000s of UAH	66412.73	277943	64	5634644
Sales per employee in 1000s of UAH	149.51	242.21	2.63	3070.65
Employment	331	545	6	4073
R&D employment [a]	0.0040	0.0155	0	0.1515
University educated [b]	0.1843	0.1333	0	1.1752
Innovation input [c]	0.0109	0.0706	0	0.9318
Innovation output [c]	0.0330	0.1232	0	0.9554
Physical capital investment [c]	0.0980	0.4832	0	12.9424
Qualitative variables [d]				
Product innovator	0.0983	0.2979	0	1
Process innovator	0.0630	0.2432	0	1
Product&Process innovator	0.0365	0.1878	0	1
Purchase of new equipment	0.1046	0.3063	0	1
Innovative implementer	0.1437	0.3510	0	1
Continuous innovator	0.0958	0.2945	0	1
Own R&D	0.0567	0.2315	0	1
Continuous R&D during 2004-2006	0.0378	0.1909	0	1
Purchase of new technologies	0.0239	0.1530	0	1
Government funding during 2004-2006	0.0113	0.1059	0	1
Most important market:				
- market within Ukraine	0.9319	0.2520	0	1
- CIS countries	0.0201	0.1406	0	1
- other international market	0.0479	0.2137	0	1
Newly established during 2004-2006	0.0264	0.1606	0	1
Downsized during 2004-2006	0.0378	0.1909	0	1

(a) As share of employees conditional on having R&D department, (b) as share of employees, (c) as share of sales, (d) as share of firms.
Total sample consists of firms 792.

Table 3: Summary statistics for innovative and non-innovative sub-samples in 2006

	Non-innovative firms, n=693		Innovative firms[e], n=99	
	Mean	**SD**	**Mean**	**SD**
Quantitative variables				
Sales in 1000s of UAH	55664	271219	141757	312409
Sales per employee in 1000s of UAH	147.34	239.78	164.69	259.42
Employment	269	457	763	837
R&D employment [a]	0.0306	0.0267	0.0424	0.0343
University educated [b]	0.1819	0.1386	0.2012	0.0871
Innovation input [c]	0.0029	0.0379	0.0667	0.1629
Innovation output [c]	0.0131	0.0878	0.1724	0.2137
Physical capital investment [c]	0.0988	0.5131	0.0921	0.1600
Qualitative variables [d]				
Product innovator	0	0	0.7878	0.4108
Process innovator	0	0	0.5050	0.5025
Product&Process innovator	0	0	0.2929	0.4574
Purchase of new equipment	0.0216	0.1455	0.6868	0.4661
Innovative implementer	0.0216	0.1455	1	0
Continuous innovator	0.0259	0.1590	0.5858	0.4950
Own R&D	0.0129	0.1132	0.3636	0.4834
Continuous R&D during 2004-2006	0.0072	0.0846	0.2525	0.4366
Purchase of new technologies	0.0086	0.0926	0.1313	0.3394
Government funding during 2004-2006	0.0072	0.0846	0.0404	0.1979
Most important market:				
- market within Ukraine	0.9380	0.2412	0.8888	0.3158
- CIS countries	0.0158	0.1249	0.0505	0.2200
- other international market	0.0461	0.2098	0.0606	0.2398
Newly established during 2004-2006	0.0259	0.1590	0.0303	0.1722
Downsized during 2004-2006	0.0403	0.1969	0.0202	0.1414

(a) As share of employees conditional on having R&D department, (b) as share of employees,
(c) as share of sales, (d) as share of firms, e) innovative firm is defined as firm which introduce at least one product innovation or implemented at least on process innovation in 2006.

Table 4: Selection equation and Innovation input equation
Dependent variable for selection eq-n: Probability of investing in innovation

Dependent variable for innovation input eq-n: Logarithm of innovation expenditures per employee

	Genaralized tobit model	
	selection equation	**innovation input equation**
	(1)	**(2)**
Firm size	0.552***	-0.247
	(0.000)	(0.271)
Human capital	0.190	3.579*
	(0.771)	(0.089)
Government funding	2.400***	2.328***
	(0.000)	(0.009)
Newly established	0.853**	1.018
	(0.039)	(0.368)
Downzised	-0.556	3.831***
	(0.199)	(0.001)
Most important market[a]:		
CIS countries	-0.253	1.382*
	(0.559)	(0.066)
Other countries	-0.289	-0.145
	(0.452)	(0.864)
Market concentration	-2.001	-1.910
	(0.177)	(0.327)
Previous success	1.812***	-
	(0.000)	
Innovation_expenditure_2005	-	1.129**
		(0.014)
Process innovation	-	0.833**
		(0.025)
Productivity_2005	-	0.451**
		(0.038)
Inverse Mills' ratio	-	0.0727
		(0.856)
Observations	792	792

Notes: (a) Reference is a national market within Ukraine

Six industry dummies are included in each regression

* significant at 10%; ** significant at 5%; *** significant at 1%
p-values are in parentheses

Table 5: Innovation output equation and Productivity equation

Dependent variable for innovation output eq-n: product innovation (0/1)

process innovation (0/1)

Dependent variable for productivity eq-n: Logarithm of sales per employee

	Product innovation	**Process innovation**	**Productivity**
	(1)	**(2)**	**(3)**
Firm size	0.3257***	0.7527***	0.0715**
	(0.000)	(0.000)	(0.019)
Previous success	1.7243***	0.2889	-
	(0.000)	(0.236)	
Government support	-0.4736	-0.7395	-
	(0.516)	(0.235)	
Newly established	0.7242	-0.0969	-0.2072
	(0.113)	(0.848)	(0.256)
Downzised	-2.3126***	-4.0945***	-0.3352**
	(0.002)	(0.000)	(0.026)
Most important market[a]:			
CIS countries	-0.8108*	-1.4514***	-0.0521
	(0.082)	(0.008)	(0.800)
Other countries	0.1187	0.2395	-0.3701***
	(0.766)	(0.656)	(0.008)
Market concentration	-3.2432	-9.3383	-
	(0.261)	(0.121)	
Physical capital investment	-	-0.0759	0.2251***
		(0.306)	(0.000)
Human capital	-	-	1.6477***
			(0.000)
Predicted innovation input	0.2562***	0.9141***	-
	(0.008)	(0.000)	
Predicted product innovation	-	-	-0.2053
			(0.411)
Predicted process innovation	-	-	1.1369***
			(0.000)
Observations	792	792	792
R-squared	-	-	0.412
Pseudo R2	0.472	0.485	-

Notes: (a) Reference is a national market within Ukraine

Six industry dummies are included in each regression

* significant at 10%; ** significant at 5%; *** significant at 1%
p-values are parentheses