Studying Complementarities between Modes of Innovation Strategies in Transition Economies

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This paper explores the existing interrelationships between the firm's innovation activities and productivity performance as well as studies complementarities among innovation strategies in transition economies. Specifically, on the basis of BEEPS V dataset and using extended CDM model, we have investigated the existence of possible complementarities between various types of innovation modes (product, process, marketing and organizational innovations) in their impact on the firm's productivity. The traditional CDM framework was modified through accounting for the simultaneous occurrence of different types of innovation inputs - in-house and out-house knowledge generation activities - and through the estimation of their joint effects on various modes of innovation. In compliance with the results of previous studies, we find that CDM model properly describes the existing interrelations between the firm's innovation activity and its productivity performance in transition economies. In particular, our results show that the firm's decisions on in-house and out-house knowledge development processes are interdependent. The study results suggest that implementation of internal R&D strategy can stimulate not only technological innovations but non-technological innovative activity as well. However, we find that external knowledge acquisition strategy has positive and statistically significant effect on innovation output only when the firm's innovation mix incorporates non-technological novelties. Our results show that only those modes of innovation output combinations that assume all the types of innovations and/or the combination of process and non-technological innovations have positive and statistically significant impact on the firm's productivity. Another vital point of this analysis is that conducting either product or process innovation in isolation will result in a negative productivity performance. The important contribution of this paper is that it tests for complementarity between innovation strategies of firms in transition economies. Our tests reveal complementarity between the following two combinations of innovations: product/process and process/non-technological innovations. The key policy implication of our findings is that while performing all the three innovation modes jointly has a positive impact on firm's performance, economically preferred options are: either to choose pure technological innovation strategy (product&process mode) or to perform strategy focused on organizational restructuring (process/non-technological mode).

JEL Classification: C12, L25, O12, O31, P31

Keywords: R&D, external knowledge acquisition, innovation, productivity, CDM model, complementarity, transition economies

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1. Introduction.

A growing number of academic literature acknowledges innovation as the main driver of a productivity growth. The relationship between the firm's innovative activity and its productivity performance has gained attention of scholars since the seminal research of Griliches (1979) and Pakes and Griliches (1980). In these studies, aimed at estimating returns to R&D, the authors have modified the traditional Cobb-Douglass production framework by the introduction of a 'knowledge production function'. The main assumption of this approach is that past and current knowledge (R&D) investments are necessary for generating a new knowledge (innovation), which in turn affects the firm's output growth.

This line of research has been further extended by Crepon, Duguet, and Mairesse (1998). The model, henceforth referred as CDM, distinguishes innovation input (research and development investments) and innovation output (knowledge). Employing structural recursive model, CDM explains productivity by the knowledge or innovation output and innovation output by research and development investments. Originally CDM comprised four equations (selectivity equation for decision to invest in knowledge, R&D intensity, innovation and productivity equations) estimated simultaneously or sequentially step-by-step. Applying this model to the sample of French manufacturing firms, Crepon, Duguet, and Mairesse (1998) find that R&D intensity has positive and significant impact on innovation output (measured by two variables: number of patents and share of innovative sales) and that innovation output, in turn, is an important predictor of the productivity of the firm. Recent studies of the link between R&D, innovation and the firm's productivity, based on the CDM model, generally has proved the main findings of Crepon et al. (1998) paper (Loof et al., 2003; Janz et al., 2004; Mairesse et al., 2005; Griffith et al., 2006; Loof and Heshmati, 2006; Benavente, 2006; Crespi and Zuniga, 2012; Hall and Mairesse, 2006). However, the majority of these CDM studies was conducted in developed countries, while the experience of CDM application in catching-up economies has received only sparse attention from the researchers to the moment.

One prominent exception to this case is a comprehensive study of the link between the innovation and firm's performance in transition economies conducted by EBRD (EBRD, 2014). On the basis of data on more than 15,000 enterprises from the Business Environment and Enterprise Performance Survey (BEEPS V) the study examines various facets of innovation, the main drivers of innovation and the impact of innovation on the firm's productivity, the role of business environment and finance in promoting innovative activities of firms in transition. Using CDM model, the study reveals the significant impact of product, process and non-technological innovation on the firm's productivity. R&D is found to be an important determinant of innovation output along with other factors such as the firm's size and age, foreign ownership, education level of employees, usage of communications and access to finance.

Other CDM-based studies of innovation-productivity link in transition economies explore: the possible effect of technological innovation on firm's productivity in Estonia (Masso and Vahter, 2008); the strength of innovation-productivity relationship across various sub-branches of the services sector in Estonia (Masso and Vahter, 2012); the impact of the government support on the manufacturing firm's R&D expenditures, innovations and productivity in Ukraine (Vakhitova and Pavlenko, 2010); the relationship of firm-level productivity to innovation and competition (Friesenbichler and Peneder, 2016); the effect of transnational corruption on the firms' innovation behavior and performance (Habiyaremyev and Raymond, 2013). At the same time some important issues related to the functioning of R&D-innovation-productivity link in catching-up economies still require more attention of academicians. In particular, existing researches while formulating 'knowledge production function' rely mainly on in-house R&D activity as an innovation input variable. The role of external knowledge acquisition in promoting the firm's innovative activity is not well studied. Besides, the way that various types of innovation strategies (technological and non-technological innovations) interact with each other while effecting the firm's performance remains relatively unstudied as well.

This paper aims at filling this gap by deepening the understanding of the performance of R&D-innovation-productivity link in transition economies. On the basis of the data from the BEEPS V survey, we explore some issues that remained relatively unexplored in EBRD (2014) study and other researches focused on transition economies. First, we extend traditional CDM model by incorporating additional (to R&D investments) innovation input strategy - external knowledge acquisition (ECA); and we analyze the impact of both strategies on innovation output. Second, we study complementarities between various types of innovation modes (product, process, marketing and organizational innovations) in their impact on the firm's productivity.

The rest of the paper is organized as follows. Section 2 examines the existing literature in the fields of research related to the interaction of alternative innovation input strategies and complementarities between the innovation modes. In this section, the research hypotheses are formulated based on the literature review. In section 3, we turn to a discussion of the research methodology, including empirical strategy and measures. The data set and characteristics of the sample used in the study are described in section four. The fifth section provides analysis into the study results. The final remarks are presented in section 6.

2. Related Literature.

Innovation Inputs: In-house R&D activity vs. External knowledge acquisition. Innovation literature distinguishes two main sources of innovation inputs: investments in internal R&D and investments in acquisition of machinery and external knowledge. The most recent empirical innovation research, based on CDM model, focuses mainly on internal R&D activity as a primary innovation input. However, some researchers (Mohnen and Hall, 2013) argue that relying only on internal R&D, without investing in the acquisition of machinery, equipment and external knowledge (EKA), may be not enough for producing innovation outputs. Thus, the role and the impact of these two types of innovation inputs on the firm's capabilities to produce new products or to introduce new processes represent special interest for this research.

The way how internal R&D and EKA influence the process of innovation is viewed differently in various theoretical approaches. The business relationship and network literature (Hakannson, 1987; Hakannson and Lundgren, 1995; Thomas and Ford, 1995; Baptista. and Swann, 1998) suggest that a firm is more successful in producing innovation, when the relevant knowledge is obtained from mutual exchange relationships with external collaborators. Vice versa, some authors (Nelson, 2000; Parisi *et al.*, 2006) emphasize the role of in-house R&D in enhancing the likelihood of introducing innovations at the firm level. Also, while the theory of transaction costs economics (Williamson, 1985; Pisano, 1990) treats internal R&D and EKA as substitutes, some researchers (Freeman 1991; Rothwell, 1992) maintain that in-house R&D and EKA complement each other in the process of innovation generation.

The empirical research of the relationship between in-house and out-house knowledge generation activities shows also mixed results. A bulk of empirical studies confirms complementarity hypothesis and shows that internal and external innovation inputs have a different significance for the different types of innovation outputs. For instance, on the basis of the representative sample of Belgian manufacturing firms, Cassiman and Veugelers (2006) analyze complementarity between internal R&D and external knowledge acquisition. They find that these two inputs represent complementary innovation activities and that the complementarity is context-specific. Parisi et al. (2006) exploiting a rich dataset of Italian firms, reveals that R&D spending enhances the probability of introducing a new product, while fixed capital spending is associated with the introduction of a process innovation. The authors argue that the effect of the fixed investment on the process innovation is complemented by internal R&D. Similarly, Conte and Vivarelli (2013) using CIS[3] dataset comprising more than 3000 Italian manufacturing companies, discuss the role of the company's investment in R&D and acquisition of technology (TA) in the introduction of new product and/or process innovations. The results of the study suggest that while R&D is connected mainly with increasing the probability of product innovation, the technology acquisition plays important role in enhancing likelihood of the process innovation. The authors argue that the relative importance of R&D and technology acquisition depends on such characteristics of the firm as size and the technological domain of a sector.

Some other studies came to slightly different conclusions with regard to the role which innovation inputs (in house R&D and/or technology acquisition) play in enhancing the probability of different types of innovation outputs and with regard to the existence of complementarity between them. Chudnovsky et al. (2006) analyzing the sample of Argentinian firms, find that R&D increases the odds of both product and process and only product innovations *vis a vis* only process innovations, while technology acquisition does not affect the relative likelihood of the innovation output outcomes. Besides, Laursen and Salter (2006) exploring the data drawn from the U.K. innovation survey, failed to prove the hypothesis that the R&D intensity of the firm is complementary to external search strategy in shaping innovative performance. Vice versa, they find the substitution effect between the openness to external search activities and internal R&D intensity. Similarly, the results of the comparative study based on large panels of Dutch and Swiss innovating firms (Arvanitis et al., 2013), suggest that while there is some evidence that both external technology sourcing and R&D cooperation positively impact innovation in isolation, there is no extra gain in performance when both are used simultaneously.

Despite its relevance the issue of the joint performance of different innovation inputs within CDM model remains relatively unstudied for countries in transition. The recent comprehensive innovation study based on CDM model conducted by EBRD (2014), uses only the internal R&D activity as an innovation input in the structural model. This study aims at filling this gap by extending traditional CDM framework through accounting for simultaneous occurrence of different types of innovation inputs (in-house R&D and EKA) and through studying their impacts on the various modes of innovation outputs for firms in transition economies. In our study we distinguish technological innovation outputs (product and process innovations) and non-technological innovation outputs (marketing and organizational innovations). Summarizing the above review, we hypothesize that:

H1: In-house R&D will be more effective in enhancing probabilities of technological types of innovations in transition economies;

H2: External knowledge acquisition will be more successful in increasing the likelihood of non-technological types of innovations in transition economies.

[3] Eurostat's Community Innovation Survey.

Complementarity of Innovation Modes. The concept of complementarity, also known as Edgeworth complementarity, refers to an idea that the economic value generated from simultaneous implementation of a number of activities or strategies is higher than their individual effects. On the basis of the lattice theory of supermodularity, a formal model of complementarity in economics and management area was developed in the works of Topkis (1978; 1987; 1998), Milgrom and Roberts (1990, 1995), Milgrom and Shannon (1994). Following these works and using properties of supermodular functions, an increasing number of studies explore complementarities of various facets of innovation activities: innovation policies; innovation inputs and innovation modes (Mohnen and Roller, 2005; Cozzarin and Percival, 2006; Schmidt and Rammer, 2007; Percival and Cozzarin, 2008; Martinez-Ros and Labeaga, 2009; Polder et al. 2009; Ballot et al, 2011).

For instance, on the basis of the CIS data from four European countries - Ireland, Denmark, Germany, and Italy, Mohnen and Roller (2005) explore complementarity in innovation policies. The paper uses innovation obstacles as negative proxies of innovation policies and tests the implied inequality conditions for supermodularity. Two phases of innovation process are distinguished in this study: the decision to innovate and the intensity of innovation. The study uncovers the existence of complementarity in innovation policies at the decision to innovate phase only, while when the targeted function is intensity of innovation the study reveals some substitutability among innovation obstacles.

Another stream of complementarity studies in innovation sphere investigates interrelations between innovation inputs such as internal R&D activities and external knowledge acquisitions. For instance, Cassiman and Veugelers (2006) study, provides a strong evidence of the existence of complementarity between internal R&D and external knowledge acquisition. Furthermore, the study suggests that the strength of the complementarity between innovation inputs depends on the extent to which the innovation process relies on basic R&D. Similarly, complementarity between internal and external investments in knowledge were found in the studies of Cohen and Levinthal (1989); Arora and Gambardella (1990); Arora and Gambardella (1994); Belderbos, Carree and Lokshin (2006).

A special interest for the goals of the current paper represent the studies that focus on exploring complementarities between product, process and organizational innovations. These studies provide a better understanding of the existing interrelationships among various modes of innovation. The possible complementarities between the various types of innovation are theoretically well-grounded (Schumpeter, 1934, 1942). For instance, introduction of a product novelty (product innovation) may require, on the one hand, establishing new production processes and the acquisition of the new equipment and skills (process innovation) and, on the other hand, applying new approaches to the organization of business processes (organizational innovation). To be successful at marketplace, all these innovative processes must be supported by relevant marketing strategies (marketing innovation).

Empirically, a number of studies confirm the existence of complementarity between two types of technological innovation: product and process novelties (Kraft 1990; Martinez-Ros, 2000; Miravete and Pernías, 2006; Reichstein and Salter, 2006; Martinez-Ros and Labeaga, 2009). Kraft (1990) investigates the relationship between product and process innovations. Using a simultaneous equation model he tests a hypothesis that these two types of innovation activities are related to each other. The study reveals a positive effect of product-innovation on process-innovation, while no significant effect of process innovation on the likelihood of the firm’s engagement in product innovation is found. Miravete and Pernías (2006), using a dataset of the Spanish ceramic tiles industry, empirically explore the existence of complementarity between product and process innovation. The results of the study show that there is significant complementarity between product and process innovations, which is mostly due to unobserved heterogeneity. The authors find also that small firms tend to be more innovative overall.

Martinez-Ros and Labeaga (2009), utilizing a database Spanish manufacturing firms, study the role of persistence in the decision of firms to implement product and process innovations and to develop those innovations. The results of the study demonstrate that persistence is important in both innovation decisions and that complementarities between product and process innovations are important too. Similarly, the hypothesis of complementarity between product and process innovation has been proved in a number of other studies: Martinez-Ros (2000) study of a large sample of Spanish manufacturing firms; Reichstein and Salter (2006) research, based on a large scale survey of UK manufacturing firms.

Owing to the theoretical and empirical evidence, discussed above, we hypothesize that:

H3: Product innovation and process innovation are complements in the firm's production function in transition economies.

Though traditionally, economic literature focuses on technological aspects of innovation (product and/or process), a number of recent research suggest that non-technological novelties such as marketing strategies and organizational changes can also enhance the firm's efficiency and complement the contribution of technological innovations to productivity growth (Cozzarin and Percival, 2006; Schmidt and Rammer, 2007; Polder et al. 2009; Ballot et al., 2011; Doran, 2012).

Schmidt and Rammer (2007) analyze the determinants and the effects of non-technological (organizational and marketing) and technological (product and process) innovations, using the firm-level data from the German CIS survey. The study reports that determinants of both types of innovations are very similar, however, technological innovations have a substantially stronger effect on profit margin compared to the effects of non-technological innovations. The study finds that the firm's organizational and marketing innovations both supplement and complement the introduction of new products and new processes. Similarly, Cozzarin and Percival (2006), on the basis of the study of Canadian firm-level data, find that innovation is complementary to many organizational strategies and that the complementary strategies differ across industries.

Polder et al. (2009), using the Netherlands firm-level data, finds that organizational innovation has the strongest productivity effects. The study reveals positive effects of product and process innovation when accompanied by organizational innovation. The study provides evidence that product and process innovations are complements in the manufacturing sector only and that organizational innovation is complementary to process innovation in both manufacturing and service sectors.

Balot et al. (2011), drawing from a large pooled sample of French and UK manufacturing firms, explore the complementarities and substitutes between product, process and organizational forms of innovation. The results of the study suggest that the efficient strategies of innovation combinations are not the same for all the firms and that the nature of complementarities in the performance between the forms of innovation has a national context and is strongly dependent on the resources and capabilities of the firm. The study reveals two main combinations of innovative activities: the "technological strategy" (product/process innovations) and the "structure oriented strategy" (organization/product innovations). At the same time, the study doesn't favor the realization of the combination of the three strategies simultaneously, because of high costs and difficulties of their implementation.

Doran (2012), using the Irish CIS firm-level data, estimates a knowledge augmented production function and tests the four different forms of innovation (organizational, process, new to the firm and new to the market innovation) for their supermodularity and submodularity. The study reports that the non-technological innovation, in the form of the organizational innovation, has a strong complementary relationship with the technological innovation. In particular, the study reveals that complementary relationships exhibit the following pairs of innovative activities: organizational and process innovation; organizational and new to the market innovation; and process and new to the firm innovation. Summarizing the existing empirical findings, we hypothesize that:

H4: Non-technological innovation and product innovation are complements in the firm's production function in transition economies.

H5: Non-technological innovation and process innovation are complements in the firm's production function in transition economies.

The empirical strategy, used for testing the above formulated hypotheses, is discussed in more detail in the next section.

3. Empirical Strategy.

In this paper we apply an augmented version of CDM model to study the structural relationships between R&D, innovation and productivity and to investigate complementarities between various innovation modes. The model represents a three-stage recursive system which consists of four equations and where each stage is modeled as a determinant of the subsequent one. The first stage comprises two equations that estimate a firm's decision to get engaged in knowledge development activities. Here we modify the conventional CDM model by including a new equation for external knowledge acquisition, which serves as a determinant of innovation output along with internal R&D activity. Besides, the equations that account for the quantitative dimensions of investments in R&D and EKA are omitted in this model. The second stage involves the estimation of innovation or knowledge production function. The predicted values of the both innovation inputs, obtained at the previous stage, are used as determinants of innovation output. The equation uses dummy variables to reflect various exclusive combinations of product, process and non-technological (organizational and marketing) forms of innovation, which are similar to those in Polder et al. (2009). The final equation represents the output production function, where predicted values of innovation from the second stage, are used as an input. At this stage, to explore complementarities between product, process and non-technological forms of innovation, we estimate the impact of exclusive combinations of innovation modes on the productivity in an augmented production function. Like in Griffith et al. (2006), the model comprises all firms rather than only innovative ones. The model is estimated sequentially, step-by step, with predicted output of one stage employed as an independent variable at the next phase. Employing predicted values rather than actual ones allows to cope with the potential endogeneity problem. For identification purposes, in each equation (except the last one), some exclusion variables ('instruments') are assumed. Besides, to correct the bias that can arise from using the predicted variables, the standard errors are bootstrapped. Let's discuss the specification of the model at each consecutive stage in more detail.

Stage 1: Innovation input (Internal R&D and External Knowledge Acquisition) equations.

At this stage two types of innovation inputs are distinguished: internal R&D and external knowledge acquisition (EKA). As already mentioned, unlike conventional CDM model, the actual model accounts only for the firm's decision to invest or not in internal research/external knowledge acquisition and doesn't consider R&D/EKA intensity decisions. Taking into account the discrete nature of the response variables in both equations and the fact that the decisions to invest in R&D and to acquire external knowledge can be jointly determined, these two equations are defined as bivariate Probit model:

$$\begin{cases} y_{1i} = 1 \; if \; y_{1i}^{*} = \beta_1^{'} x_{1i} + \varepsilon_{1i} > 0; \; and \; y_{1i} = 0 \; otherwise; \\ y_{2i} = 1 \; if \; y_{2i}^{*} = \beta_2^{'} x_{2i} + \varepsilon_{2i} > 0; and \; y_{2i} = 0 \; otherwise; \end{cases} \quad (1)$$

where y_{1i}^{*} is the latent R&D investment decision variable and y_{1i} is the indicator variable that equals 1 if a firm decides to invest in R&D. Similarly, y_{2i} is dummy variable, which equals to one when a firm makes investments in external knowledge acquisition and y_{2i}^{*} is connected with its latent variable. The β_1' and β_2' are the vectors of parameters to be estimated, while ε_{1i} and ε_{2i} are error terms which are assumed to follow a joint normal distribution with zero mean and variance equal to 1. Another assumption with regard to error terms is that $\varepsilon_{1i}$and ε_{2i} are correlated with correlation coefficient ρ. The vectors x_{1i} and x_{2i} include the independent variables, which explain the firm's decision to get engaged in R&D and in EKA respectively. In our model, both vectors generally share the same set of variables, with the only exception: while important determinant of the decision to invest in R&D is patent protection, in EKA equation this variable is replaced by intensity of computers usage. The explanatory variables included in x_{1i} and x_{2i} vectors are described in more detail below:

- ***Patent*** - is a dummy variable, which shows whether establishment has ever been granted a patent (included in x_{1i} vector but not in x_{2i} vector).
- ***Computers_usage***- percentage of workforce that use computers regularly (included in x_{2i} vector but not in x_{1i} vector).
- ***Financing_wc*** - financing of working capital variable. This variable reflects the percentage of the working capital financed by banks and non-bank institutions and is used to control for the imperfections of the financial markets.
- ***Univeristy_degree*** – percent of full-time employees with university degree, reflects the quality of human capital employed by establishment;
- ***Size*** - *firm's* size, which contain three dummy variables: small (6-19 employees), medium (20-99 employees), and large (100 and more employees);
- ***Age*** – log of the age of the establishment in years;
- ***Foreign*** – dummy variable, which shows whether the foreigners have a majority in the ownership;
- ***State*** – dummy variable, which indicates whether the state has a majority in the ownership;
- ***Subsidy*** - is a dummy variable, which shows whether an establishment has received any subsidies from the national, regional or local government or from the European Union sources over the last three years.

- ***Country and Industry dummies***[4] - which reflect country and industry fixed effects respectively.

The variable ***Subsidy*** along with variables ***Patent*** and ***Computers_usage*** is considered as an instrument for R&D and EKA indicators.

The two-equation system (1) is estimated simultaneously by simulated maximum likelihood estimation technique. Ignoring parameters to be estimated, the log–likelihood takes the following form:

$$lnL = lnL(y_{1i}, y_{2i}|x_{1i}, x_{2i}) = l_1(y_{1i}|x_{1i}) * l_2(y_{2i}|x_{2i}) \ (2)$$

The likelihood function (2) is built upon a bivariate probit model. Since the system of equations (1) represents seemingly unrelated equations model, the contributions to likelihood function discussed above are connected by the correlation coefficient of the error terms. The log–likelihood function is maximized using the Conditional Mixed Process program (CMP) (Roodman, 2011), which applies GHK-type numerical simulation algorithm.

Stage 2: Innovation output equation (Multinomial Logit Model).
On the second step, predicted values of innovation inputs obtained on the previous stage are used to estimate knowledge production function or innovation outputs. Generally, we consider three types of innovation output in this study: product, process and non-technological (marketing and/or organizational) innovations. However, following Polder et al. (2009) and Ballot et al. (2011), in order to distinguish the firms that implement the different forms of innovation simultaneously, we apply the exclusive combinations of innovation modes. As a result, we obtain eight exclusive combinations of innovation modes, which are represented by the following dummy variables:

- ***Innovation_000*** – no innovation form is implemented by a firm;
- ***Innovation_001*** – a firm implements only the non-technological type of innovation;
- ***Innovation_010*** – a firm implements only the process type of innovation;
- ***Innovation_011*** – a firm implements only the process and non-technological types of innovation;
- ***Innovation_100*** – a firm implements only the product type of innovation;
- ***Innovation_101*** – a firm implements only the product and non-technological types of innovation;
- ***Innovation_110*** – a firm implements only the product and process types of innovation;
- ***Innovation_111*** – a firm implements all the three types of innovation.

Given eight types of innovation modes and following Ballot et al. (2011), in this study we apply multinomial logit model as the estimation techniques. We set the base category to be ***Innovation_000*** – the situation when none of innovation form is implemented by a firm. Then the probability that a firm *i* will choose *j* innovation mode can be determined as:

$$Prob\ (y_{3i} = j|x_{3i}) = \frac{e^{\beta_j' x_{3i}}}{1 + \sum_{k=1}^{J} e^{\beta_k' x_{3i}}}\ , for\ j = 0, \dots, 7, \beta_0 = 0 \ \ (3)$$

[4] The industries in the study are: Manufacturing (Food; Wood; Publishing, printing and recorded media; Chemicals; Plastics&Rubber; Non-metallic mineral products; Fabricated metal products; Machinery and equipment; Electronics; Precision instruments; Furniture); Retail; Other Services (Wholesale; IT; Hotel and restaurants; Services of motor vehicles; Construction section; Transport; Supporting transport activities; Post and telecommunications).

where x_{3i} is a vector of explanatory variables for a firm i, and β_j' is vector of parameters for the choice j, to be estimated. The vector of explanatory variables x_{3i} includes the following indicators:

- predicted probabilities of the firm's engaging in internal R&D and in EKA activities, obtained from the previous stage;
- ***Main Market*** – comprises three indicators – *local*, *national*, *international* – which signify that the main product is sold on the local, national or international markets respectively;
- ***Email*** – dummy variable, which means that the establishment uses e-mail for communication with its business partners;
- some explanatory variables used at the previous stage, such as: educational level, access to finance, size, age, ownership of the firm, country and industry controls.

Variables ***Main Market*** and ***Email*** serve as the instruments for innovation.

The model (3) implies computation of seven log-odds ratios of the following form:

$$Ln\left[\frac{P_{ij}}{P_{ik}}\right] = x_{3i}'\left(\beta_j - \beta_k\right) = x_{3i}'\beta_j \text{ , } if\ k = 0 \quad (4)$$

The coefficients of the model will be estimated through maximizing the log likelihood function:

$$\ln L = \sum_{i=1}^{N} \sum_{j=0}^{J} d_{ij} \ln P\left(Y_i = j\right) \qquad (5)$$

where N is the number of subjects on which data have been collected. For each subject, d_{ij} is defined equal to one, if a subject i chooses the alternative innovation mode j, and is defined as zero otherwise, for the J+1 possible outcomes (McFadden, 1984; Green, 2003). Following Polder et al. (2009) and Ballot et al. (2011), we predict propensities for each possible combination of the innovation mode, and use them as innovation proxies at the next stage. To correct for bias, we use bootstrapped standard errors.

Stage 3: Augmented Production Function equation.

The last equation of the structural model estimates labor productivity using linear OLS regression. ***Productivity*** (y_{4i}) is measured as a log of ratio of total sales to the number of employees and is modeled as a function of exclusive combination of innovation modes and a vector of exogenous variables x_{4i}. The model is formulated in the following way:

$$y_{4i} = \left[\sum\nolimits_{klm} \gamma_{klm}' Innovation(product = k; process = l; non\_tech = m)\right] + \beta_4' x_{4i} + \varepsilon_{4i}, \qquad (k, l, m \in \{0,1\}) \quad (6)$$

In this model the innovation is presented by the eight exclusive modes discussed in the previous section, where the ***Innovation_000*** mode, which assumes no innovation activity, is used as a reference category. To cope with the potential endogeneity of innovation we employ the predicted propensities of exclusive combinations calculated at the previous stage. Compared to vector x_{3i}, the vector x_{4i} includes two additional variables:

- ***Unofficial competition***- dummy variable, which shows whether the establishment faces competition from unregistered or informal firms;
- ***Location*** - dummy variable, which indicates whether the establishment is located in the capital city.

The γ'_{klm} and β'_4 are the vectors of parameters to be estimated, while ε_{4i} is the error term which is assumed to follow a joint normal distribution with zero mean and variance equal to 1.

The productivity equation per se represents a Cobb-Douglas production function, which must contain the physical and human capital. However, we don't control the physical capital, in this equation, because the inclusion of capital per employee or capital utilization variables in the model substantially reduces the sample. The inability to control the physical capital creates the potential danger of overestimation of the impact of innovation on the labor productivity.

Testing complementarities among Innovation forms. The concept of complementarity between strategies or policies in the management area, rests upon the theory of supermodularity, developed in the works of Topkis (1978; 1987; 1998), Milgrom and Roberts (1990, 1995), Milgrom and Shannon (1994). According to these papers, the function $f: R^2 \to R$ is supermodular or has increasing differences in (X; Y) (and thus there is the complementarity between the two strategies - X and Y) if for all $X' > X, f(X'; Y) - f(X; Y)$ is non-decreasing in Y. To say distinctly, two strategies are complements of each other when introducing one of them while the other is already being implemented, results in higher marginal increase in the firm's performance compared to the situation when the strategy is being implemented in isolation. The function that relates such strategies to the firm's performance is called a supermodular function.

In this study we apply, with small modifications, the supermodularity approach, used in Ballot et al. (2011), to test complementarity between product, process and non-technological forms of the innovation strategy. For instance, Ballot et al. (2011) explore the existence of complementarity between product, process and organizational innovation and distinguish between conditional and unconditional complementarity. According to the authors, any two strategies are unconditional complements if the complementarity between them occurs independently of the presence or absence of the third strategy. In this case, the firm's performance function is supermodular in these two innovation strategies. When the existence of complementarity between two strategies is dependent on the presence or absence of the third strategy, such complementarity is called conditional. Following Ballot et al. (2011) we formulate three slightly modified sets of testable restrictions:

1) Complementarity between product and process forms of innovation:
R0: γ_110 - γ_010 - γ_100>0 (absence of non-technological innovation)
R0: γ_111+ γ_001 - γ_011 - γ_101>0 (presence of non-technological innovation)

R1: γ_110 - γ_010 - γ_100=0 (absence of non-technological innovation)
R1: γ_111+ γ_001 - γ_011 - γ_101=0 (presence of non-technological innovation)

where, γ_001 - is regression coefficient of **Innovation_001** dummy variable obtained from the estimation of augmented production function (6) and which reflects the semi-elasticity of productivity with regard to this innovation mode. Similarly, the terms γ_010; γ_011; γ_100; γ_101; γ_110; γ_111 represent regression coefficients of **Innovation_010**; **Innovation_011**; **Innovation_100**; **Innovation_101**; **Innovation_110**; **Innovation_111** innovation mode dummies respectively.

The simultaneous acceptance of the both R0 restrictions indicates the existence of a strict unconditional complementarity between product and process innovation and suggests that firm's performance is supermodular in product and process innovation. If only one of R0 restrictions is true, then complementarity between product and process innovation is conditional on the presence or absence of the non-technological innovation. Vice versa, if one or the both expressions are proved to be negative then product and process innovations are conditional or unconditional substitutes of each other. The same logic applies to testing complementarities between other pairs of innovation strategies.

2) Complementarity between product and non-technological forms of innovation:
R0: $\gamma\_110 - \gamma\_100 - \gamma\_001>0$ (absence of process innovation)
R0: $\gamma\_111+\gamma\_010 - \gamma\_110 - \gamma\_011>0$ (presence of process innovation)

R1: $\gamma\_110 - \gamma\_100 - \gamma\_001=0$ (absence of process innovation)
R1: $\gamma\_111+\gamma\_010 - \gamma\_110 - \gamma\_011=0$ (presence of process innovation)

3) Complementarity between process and non-technological forms of innovation:
R0: $\gamma\_011 - \gamma\_010 - \gamma\_001>0$ (absence of product innovation)
R0: $\gamma\_111+\gamma\_100 - \gamma\_110 - \gamma\_101>0$ (presence of product innovation)

R1: $\gamma\_011 - \gamma\_010 - \gamma\_001=0$ (absence of product innovation)
R1: $\gamma\_111+\gamma\_100 - \gamma\_110 - \gamma\_101=0$ (presence of product innovation)

The acceptance of any of R0 restrictions in the first, second and the third sets of constraints, will provide support for the hypotheses **H3, H4**, **H5** respectively, formulated earlier in the literature review section.

4. Sample and Data Description.
The main source of the data for the research is the micro-level dataset from the fifth round of the Business Environment and Enterprise Performance Survey (BEEPS V)[5]. The survey was conducted by the European Bank for Reconstruction and Development (EBRD) and the World Bank Group (the World Bank) for 15,523 firms in 29 countries[6] in the European and Central Asian regions in the period of 2012-2014. The sample was selected using stratified random sampling techniques. Three levels of stratification were used in all countries: industry, establishment size and region. The more detailed description of the sampling methodology can be found in the Sampling Manual[7]. However, the final sample used for the analysis is substantially lower than the initial one. Such a drastic reduction in the sample size mainly is the result of non-responses, which in turn is caused by the reasons that aren't identified and thus that can't be analyzed. Since we can only take into account this issue while making interpretation of the study results.

Table 1 reports the descriptive statistics for the variables used in the model in different equations. According to the table, on average 9.7% of firms invest in R&D, while 18.8% of companies prefer to acquire external knowledge. Product innovations have highest proportions among innovation output types (22.3%) followed by marketing innovations (21.1%), organizational innovations (19.6%) and process innovations (17.7%). Generally, 27.5 percent of firms perform either marketing or organizational innovations. On average, the labor productivity of firms is equal to 63,153 USD

[5] https://www.enterprisesurveys.org/
[6] Albania, Armenia, Azerbaijan, Belarus, Bosnia, Bulgaria, Croatia, Czech, Estonia, Georgia, Hungary, Kazakhstan, Kosovo, Kyrgyzstan, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Tajikistan, Turkey, Ukraine, Uzbekistan.
[7] http://www.enterprisesurveys.org//~/media/GIAWB/EnterpriseSurveys/Documents/Methodology/Sampling_Note.pdf

sales per employee. More than fifteen percent of the sample has ever been granted a patent, almost thirty-four percent of the employed have higher education and 45.3% percent of workforce use computers regularly. Only 8.3% of the companies in the sample receive subsidies from the government or EU and almost twelve percent of the working capital of the firms is financed from external funds. The average establishment employs 67 workers and the mean of the firms' age in the sample is approximately 35 years. The highest proportion of the sample represents small firms (52.7%), followed by medium (31.9%) and large companies (12.9%). Almost two percent of the firms are owned by a state and 7.5% by foreigners. The firms mainly operate at local (57.9%) and national (35.3%) markets, while at global markets compete only 6.8% of the sample. About twenty-two percent of the companies are located in the capital city and 37.5% of the firms face with the competition of the unofficial entities. Almost ninety percent of the establishments use email for communication with their partners.

Table 1. Summary statistics (means and std. deviations) for the whole sample

Variables	**Mean**	**Standard deviation**	**Number of observations**
R&D investments (dummy)	.097	.296	15,523
EKA investments (dummy)	.188	.391	7,181
Product innovations (dummy)	.223	.416	15,523
Process innovations (dummy)	.177	.382	15,523
Marketing innovations (dummy)	.211	.408	15,523
Organizational innovations (dummy)	.196	.397	15,523
Non-technological innovations (dummy)	.275	.446	15,523
Productivity (USD)	66,153	109,061	11,734
Patent (establishment has ever been granted a patent)	.153	.360	7,085
Percentage of workforce that use computers regularly	45.35	34.41	6,809
University degree (percentage)	33.96	31.41	14,768
Working capital financed from external funds (percent)	12.05	23.44	14,704
Subsidy (dummy)	.083	.276	15,368
Firm's age	34.9	202.5	15,514
Firm's size	67.01	274.77	15,418
Small firms	.527	.499	15,523
Medium firms	.319	.466	15,523
Large firms	.129	.335	15,523
Foreign ownership (dummy)	.069	.253	15,523
State ownership (dummy)	.018	.133	15,523
Main market: local (dummy)	.579	.493	15,390
Main market: national (dummy)	.353	.478	15,390
Main market: global (dummy)	.068	.252	15,390
Email (dummy)	.871	.335	15,480
Location in capital (dummy)	.226	.418	15,523
Unofficial competition (dummy)	.375	.484	14,165

5. The Empirical Findings.

In this section, the estimation results of the modified CDM model are presented.

Innovation input stage. Table 2 presents the estimated results for the first stage of CDM model. This stage comprises bivariate SUR probit model (system of equations 1), which specifies the probabilities of investing in R&D and acquiring external knowledge (EKA). First, the results reveal that these two decisions are interdependent within the establishment, since the residuals of the corresponding equations are significantly correlated with each other. Thus the joint estimation of these two equations seems to be an appropriate decision. Further, we find that possessing of formal protection (patents, trademarks, licenses) and having the educated human resource stimulate investments in R&D (both effects are statistically significant at p<0.01 level). The analysis of marginal effects shows that availability of formal patent protection increases probability of R&D by almost 10% (with a standard deviation of 0.013), while the marginal effect of one percent increase of personal with university degree is 0.001 (.0001). The regular use of computers, in turn, increases the probability of the external knowledge acquisition (significant at 1% level). In particular, one percent increase in workforce that use computers regularly raises the probability of the external knowledge acquisition by 0.1% (with standard deviation of .0001). As expected, the likelihoods of the positive outcome for the both decisions (to invest in R&D and to acquire external knowledge), increase with the size of the firm, availability of subsidies, development of credit markets and foreign ownership.

Table 2. Estimations results for Innovation Input equations (R&D and EKA) by sectors

Variables	**R&D equation**		**External Knowledge Acquisition Equation (EKA)**	
	Regression coefficients	**Marginal Effects (Dy/Dx)**	**Regression coefficients**	**Marginal Effects (Dy/Dx)**
Patent (establishment has ever been granted a patent)	.4074 *** (.0534)	.1048*** (.0135)	-	-
Percentage of workforce that use computers regularly	-	-	.0048*** (.0007)	.0012*** (.00017)
Working capital financed from external funds	.0031*** (.0007)	.00078*** (.0002)	.0015* (.0008)	.00037* (.0002)
University degree	.005*** (.0007)	.0013*** (.00019)	.0013 (.0008)	.00034 (.0002)
Firm's size (small)	-.2588*** (.0547)	-.0666*** (.0140)	-.2878*** (.0561)	-.0739*** (.0143)
Firm's size (medium)	-.2061*** (.0503)	-.0531*** (.0129)	-.1752*** (.0514)	-.0450*** (.0131)
Log of Firm's age	-.0235 (.0245)	-.0061 (.0063)	.021 (.0248)	.0054 (.0064)
Foreign ownership	.1159* (.0642)	.0298* (.0165)	.1916*** (.0639)	.0493*** (.0164)
State ownership	-.0864 (.1461)	-.0222 (.0375)	.1568 (.1413)	.0403 (0363)
Subsidy	.2911*** (.0561)	.0749*** (.0143)	.2497*** (.0577)	.0642*** (.0148)
Country effects	Yes		Yes	
Industry effects	Yes		Yes	
Correlation of residuals (Rho)	.2368*** (.0277)			
N (number of observations)	6,523		6,523	
Notes: Standard errors in parentheses; *** — significant at p < 0.01 level; ** — significant at p < 0.05 level; * — significant at p < 0.1 level.				

In accordance with the Schumpeterian approach to innovation and findings from recent studies (Cohen and Klepper, 1996), the firm's size is the important determinant of the firm's decision to invest in R&D and to acquire external knowledge. Larger establishments, enjoying economies of scale and scope and having greater market power, possess better opportunities to mobilize necessary financial resources, and thus they show higher propensity for innovation. Small and medium size establishments have substantially lower probability of such investments (statistically significant at 1% level in both equations), compared to large companies. Both R&D and EKA equation reveal similar marginal effects. In R&D equation marginal effects are -.06 (0.014) and -.05 (.013) for small and medium companies respectively: while in EKA equation the corresponding figures are -.07 (0.014) and -.04 (0.013).

As mentioned above, the probabilities of decisions to invest in R&D and to acquire external knowledge are also positively affected by availability of subsidies from government or international sources (statistically significant at $p<0.01$ in both equations); development of credit markets (significant at 1% level in R&D equation and at 10% level in EKA equation); and availability of foreign ownership (significant at 10% level in R&D equation and at 1% level in EKA equation). These factors increase propensities of innovation via providing access to finance and ensuring transfer of external knowledge and skills (foreign ownership) to the companies. The comparison of marginal effects shows that both subsidies and credit markets have slightly stronger impact on R&D decisions, while the availability of a foreign owner is a more prominent determinant in EKA equation. For instance, the availability of subsidies increases the probability of R&D by 7% (0.014) and the probability of EKA by 6% (0.015). At the same time under foreign ownership the probability of EKA raises by 5 percent (0.016) while the probability of R&D only by 3 percent (0.017). Other controls, such as a firm's age and ownership type exert no influence on R&D and EKA decisions.

Innovation output stage. The special interest for us represents the effects of two endogenous variables 'investment in R&D' and 'acquisition of external knowledge' on the exclusive combinations of various innovation modes. According to table 3, internal R&D activity is the important predictor (statistically significant at $p<.05$) of innovation output. In-house R&D investments increase probability of occurrence for practically all exclusive combinations of its modes (the only exception is the combination of process and non-technological innovation). Thus, contrary to our H1 hypothesis, the study results suggest that internal knowledge inputs are effective in promoting innovation irrespective of their type.

However, in support of our H2 hypothesis, we find that EKA strategy has the positive and statistically significant effect on innovation (at $p<0.01$ level) only when the exclusive combination of innovation modes includes the non-technological form of innovation. In situation when innovation output strategy lacks non-technological innovation EKA variable negatively effects the innovation output, but these impacts are not statistically significant.

Thus, despite our expectations that in-house knowledge development will enhance the probabilities of technological innovation only, the analysis of hypothesis testing shows that internal R&D strategy can be considered as an effective instrument for promoting any kind of innovative activity. At the same time, the empirical findings suggest that a firm can benefit from the choice of the external knowledge acquisition option only when its innovation strategy assumes implementation of non-technological novelties.

In compliance with the existing empirical findings (Polder et al, 2009; Leeuwen Van, 2008), we find that the appliance of electronic communication promotes the innovation activities of the firm. This conclusion is true practically for all combinations of innovation types with the only exception when process innovation is conducted alone. Electronic communication facilitates the exchange of information between economic agents and in this way it stimulates the innovation activities of firms.

Table 3. Estimations results for Exclusive Innovation output combinations (Multinomial Logit Model)

Variables	Exclusive combinations of Innovation output [8]						
	Non-technological innovation only (Innov_0_0_1)	Process innovation only (Innov_0_1_0)	Process and non-technical innovation (Innov_0_1_1)	Product innovation only (Innov_1_0_0)	Product and non-technical innovation (Innov_1_0_1)	Product and process innovation (Innov_1_1_0)	All types of innovation (Innov_1_1_1)
Investments in R&D (predicted probability)	3.417*** (.9996)	3.529** (1.794)	2.234 (1.560)	6.740*** (1.251)	3.696*** (1.063)	6.413*** (1.598)	7.271*** (1.0198)
Investments in EKA (predicted probability)	2.904*** (.9853)	-.9308 (2.043)	5.341*** (1.627)	-1.236 (1.456)	3.812*** (1.261)	-.2322 (1.769)	5.681*** (.9587)
University degree	-.0003 (.0028)	.0045 (.0034)	.0001 (.0030)	.0018 (.0029)	.0034 (.0029)	-.0052 (.0034)	-.0047 (.0026)
Log of Firm's age	-.0006 (.0660)	.1021 (.1036)	-.0021 (.0783)	.0142 (.0632)	.0165 (.0703)	.0701 (.0820)	-.0020 (.0673)
Firm's size (small)	1.519*** (.1995)	1.311*** (.3072)	1.403*** (.2238)	1.933*** (.1977)	1.510*** (.2598)	1.941*** (.2383)	1.627*** (.1832)
Firm's size (medium)	.0125 (.1536)	.0933 (.2682)	.0356 (.1984)	.3427* (.1812)	.0959 (.1722)	.2107 (.1842)	.3108** (.1463)
Foreign ownership	.1040 (.1909)	.2613 (.3350)	.1143 (.1997)	-.0662 (.1879)	.4245** (.1905)	.2055 (.2608)	-.1676 (.1701)
State ownership	-.5014 (.4009)	-.3471 (2.642)	-.5313 (.5670)	-.3564 (.4235)	-.4583 (.4923)	-.2871 (2.2008)	-.3181 (.3568)
Working capital financed from external funds	.0004 (.0026)	.0031 (.0033)	.0012 (.0029)	-.0052* (.0028)	-.0007 (.0028)	-.0032 (.0035)	.0007 (.0026)
Main market: local	.2463** (.1156)	.1635 (.1639)	.2673* (.1515)	.3264** (.1323)	.1755 (.1250)	.2338 (.1635)	.0417 (.1206)
Email	.5535** (.2269)	-.135913 (.2806)	1.109*** (.2614)	.3818* (.1982)	.6522*** (.2210)	1.492*** (.4543)	.9185*** (.2423)
Country effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N (number of observations)	6,082	6,082	6,082	6,082	6,082	6,082	6,082
Notes: Bootstrapped Standard errors in parentheses; *** — significant at $p < 0.01$ level; ** — significant at $p < 0.05$ level; * — significant at $p < 0.1$ level.							

However, small firms show higher probabilities for innovative activities compared to the large companies. This study result is supported by the previous empirical evidence. For instance, Conte and Vivarelli (2013) suggest that while larger firms are more likely to decide positively on the investment in R&D activity, smaller companies, among those who have already invested in knowledge, are more flexible in terms of producing innovative output. Besides, on the basis of the previous empirical studies (Pavitt et al., 1987) Hall argues that "…the relationship between innovative activity and firm size is largely U-shaped, and that smaller firms show greater innovative activity than formal R&D activity." (Hall, 2011; p. 173).

[8] 'No innovation' alternative is used as a base category

Productivity stage. The final stage of the CDM model estimates the impact of exclusive combinations of innovation modes on the firm's labor productivity. The results of this stage, presented in Table 4, suggest that the innovation output effects labor productivity positively and statistically significantly only when the firm performs all the three types of innovation or when it combines process with non-technological innovation. If product and process innovations are performed separately, their impact on the labor productivity is negative (statistically significant at 5% level). Thus, pure technological innovative efforts, not supported by relevant marketing activities or organizational changes may have undesirable effect on the firm's performance, at least in the short-run. Other combinations of innovation modes have statistically no significant impact on the firm's performance. This indicates the possible complementarity between technological and non-technological innovation modes (the test for complementarity between innovation modes is provided in the next section). The results of the study, generally support the existing empirical evidence (Polder et al, 2009). However, there are some contradictions to Polder's finding that organizational (non-technological) innovation is the main source of productivity. We find no significant impact of non-technological innovation on productivity when it's conducted in isolation.

Table 4. Estimations results for production function

Variables	**Log of productivity**
Innovation_1_1_1	1.1461*** (.3717)
Innovation_1_1_0	.9127 (1.0905)
Innovation_1_0_1	.2892 (.7162)
Innovation_1_0_0	-1.2721** (.5912)
Innovation_0_1_1	3.716*** (1.106)
Innovation_0_1_0	-2.956** (1.222)
Innovation_0_0_1	-.0462 (.7266)
University degree	.0055*** (.00098)
Log of Firm's age	.0136 (.0293)
Firm's size (small)	.0819 (.0987)
Firm's size (medium)	.1114 (.0748)
Foreign ownership	.3314*** (.0864)
State ownership	-.2917** (.1473)
Working capital financed from external funds	.0023** (.00095)
Unofficial competition	-.0783** (.0342)
Location in capital	.1944*** (.0488)
Country effects	Yes
Industry effects	Yes
N (number of observations)	4,780
Notes: Bootstrapped Standard errors in parentheses; *** — significant at $p < 0.01$ level; ** — significant at $p < 0.05$ level; * — significant at $p < 0.1$ level.	

Other important predictors of labor productivity are foreign and state ownership, location in capital, and competing unregistered firms. When the majority of the owners of the firm is foreigner the labor productivity increases by 33 percent; vice versa state ownership reduces productivity performance by 29 percent. Location in capital causes the increase in the outcome variable by 19% while facing unofficial competition reduces labor productivity by 8%. Human capital and credit market development also have statistically significant impact (p<0.01) on labor productivity, though the magnitude of this effect is comparatively not so big. Besides, we have found no statistically significant effect of firm's age and size on labour productivity.

Testing complementarities between innovation modes. In this paper, following Ballot et al. (2011) we test conditional complementarity and substitutability between three pairs of innovation modes. In compliance with the existing empirical research, the results of the tests presented in table 5 reveal no presence of supermodularity between the three modes of innovation. At the same time, we have found a number of cases of complementarity and substitutability between pairs of innovation modes dependent on the presence or the absence of the third innovation strategy.

Table 5. Tests of complementarities between Innovation types

Combination of innovation types	Test statistics			
	Sign	Chi2	df	P-value
Product/Process Innovation				
All		11.82	2	0.0027
1) inov_1_1_0 - inov_1_0_0 - inov_0_1_0= 0	+	7.43	1	0.0064
2) inov_1_1_1- inov_1_0_1- inov_0_1_1+ inov_0_0_1 = 0	-	3.71	1	0.0541
Product/Non-technological Innovation				
All		12.62	2	0.0018
1) inov_1_0_1 - inov_1_0_0 - inov_0_0_1= 0	+	2.40	1	0.1214
2) inov_1_1_1- inov_1_1_0- inov_0_1_1+ inov_0_1_0 = 0	-	12.20	1	0.0005
Process/Non-technological Innovation				
All		18.11	2	0.0001
1) inov_0_1_1 - inov_0_1_0 - inov_0_0_1= 0	+	17.53	1	0.0000
2) inov_1_1_1- inov_1_1_0- inov_1_0_1+ inov_1_0_0 = 0	-	0.61	1	0.4344

Product&process innovation. In support of our H3 hypothesis we find that this pair of innovation strategies is characterized by complementarity when non-technological innovation is not performed (statistically significant at 1% level); while when non-technological innovation is implemented, product and process innovations substitute each other (statistically significant at 10% level). It should be mentioned, that if the former conclusion is generally in line with the existing research (Polder et al, 2009; Ballot et al., 2011), the latter one finds very scarce support in the empirical literature. Anyway, the testing results suggest that for the firm in transition economy a more productive option is: to perform only the technological innovation (product&process modes) strategy; or when non-technological innovation is already enacted, to supplement it by either product or process innovation.

Product&non-technological innovation. We find no complementarity relations between product and non-technological innovations. However, not in line with previous findings, the results of the tests indicate that this pair of innovation modes is substitutes when the process innovation is present (statistically significant at 1% level). According to the results of this test, joined implementation of product and non-technological innovations doesn't represent a good option for a firm in transition. Thus the empirical evidence provides no support for H4 hypotheses.

Process&non-technological innovation. According to table 5, process and non-technological innovations complement each other (statistically significant at 1% level), but only in the case when product innovation is not performed. Thus, the research hypotheses H5 is partially supported by the results of our analysis.

Summarizing three pairwise tests of complementarity, one may conclude that while performing all three innovation modes jointly has a positive impact on the firm's performance, economically preferred options are: either to choose pure technological innovation strategy (product&process

modes) or to perform strategy oriented on the organization restructuring, which combines process and non-technological innovations. These two strategy options are similar to innovation strategy typologies developed in Ballot et al. (2011).

6. Summary and Conclusions.

This paper explores the existing interrelationships between innovation activities and productivity performance of firms as well as complementarities between innovation strategies in transition economies. Specifically, on the basis of BEEPS V dataset and using extended CDM model, we have investigated the existence of possible complementarities between various types of innovation modes (product, process, marketing and organizational innovations) in their impact on the firm's productivity. The traditional CDM framework was modified through accounting for the simultaneous occurrence of different types of innovation inputs - in-house and out-house knowledge generation activities - and through the estimation of their joint effects on various modes of innovation. In compliance with the results of the previous studies, we have found that CDM model properly describes the existing interrelations between the firm's innovation activity and its productivity performance in transition economies.

In particular, our results show that the firm's decisions on in-house and out-house knowledge development processes are highly interdependent and generally share the same determinants. Both strategies of knowledge generation require the availability of finance which can be ensured through: an easy access to financial markets; subsidies from a government or international donors; foreign direct investments. The latter may represent not only the important financial source but the source of advanced knowledge and know-how transfer as well. However, the primary supplier of finance necessary for stimulating innovations is the firm itself. We find that large firms substantially outperform small and medium enterprises in terms of innovation activity. According to Schumpeter, such an advantage of large firms in knowledge development process can be explained first of all by their capabilities to mobilize necessary financial resources. We think that main policy implication stemming from these study results is that providing ease access to financial resources is a crucial prerequisite necessary for promoting knowledge development activity in transition economies.

In support of the existing findings, we reveal that internal R&D activity is highly dependent on the patent protection. Thus, the enhancement of the legal framework and establishing the rule of law that secure the property rights, can be considered as important ways for stimulating firm's R&D investment decisions. This is especially true for the countries where the firms' innovation activity is very low and property rights guaranteeing mechanisms are very poor.

Further, based on the results of previous studies, we have formulated and tested hypotheses that internal R&D is linked mainly to technological types of innovation (product and process) while external knowledge acquisition to non-technological innovation modes (marketing and organizational). Contrary to our expectations the study results suggest that the implementation of internal R&D strategy can stimulate not only technological innovations but non-technological innovative activity as well. However, in support of our second hypothesis, we have found that EKA strategy has the positive and statistically significant effect on the innovation output only when the firm's innovation mix incorporates non-technological novelties.

Unsurprisingly, the appliance of electronic communication increases the probability of occurrence practically for all the combinations of innovation modes. This result supports the previous findings on the role of ICT in promoting innovative activities of companies (Polder et al, 2009; Leeuwen Van, 2008).

Concerning the links of various modes of innovation output to the firm's productivity performance, our results show that only the combinations that assume all the types of innovations and/or process and non-technological innovation have positive and statistically significant impact on the firm's productivity. Though these results generally support the existing empirical evidence (Polder et al, 2009), we have found no significant impact of non-technological innovation on productivity when it's conducted in isolation. Another vital point of this analysis is that conducting either product or process innovation in isolation will result in a negative productivity performance.

The important contribution of this paper is that it tests for complementarity between innovation strategies of firms in transition economies. Our tests reveal complementarity between the following two combinations of innovations: product/process and process/non-technological innovations. These results, generally, resemble the findings for developed (UK and France) markets (Ballot et al., 2011). The only difference is that for UK sample complementarity was proved for product and organizational innovation strategies, while in this paper complements are process and non-technological innovations. Following Ballot et al. (2011), we call the first pair of complementary innovations 'technological strategy' while the second one 'restructuring strategy'. The key policy implication of our findings is that while performing all the three innovation modes jointly has a positive impact on the firm's performance, economically preferred options are: either to choose pure technological innovation strategy (product&process mode) or to perform organization restructuring oriented strategy (process/non-technological mode).

This study provides some new insights on the functioning of the extended CDM model and on the complementarity between innovation strategies in transition economies. Still, cross-sectional nature of the dataset used in this study limits understanding of some important issues such as: the impact of the firm specific factors on its innovation and productivity performance; dynamic relationships between R&D, innovations and the firm's performance. We think that the appliance of panel data sets will allow scholars to clarify these issues.

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