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Abstract

In this paper, perform a detailed longitudinal analysis on the innovation performance in nine European countries by using data stemming from the Community Innovation Survey. The temporal dimension of our dataset includes the period during the financial crisis of 2008 as well as the period after the crisis. As such, it allows us to fully evaluate the changes in the innovation processes within the countries during and after the crisis. Our findings suggest that there are no significant differences between the countries in the determinants for firms which decide to enter the innovation process. However, the effect of innovation output over labor productivity varies between economies: there is a positive relationship in the more developed economies compared to a negative or neutral relationship in the less developed. We use these results to speculate that the national innovation system in developing economies becomes more vulnerable in periods of financial crises.

Keywords: CIS, European countries, national innovation systems, longitudinal studies, labor productivity.
JEL classification: C33, C36, O31; O33

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1. Introduction

Productivity, defined as the output per unit of input, and its growth, relies on a combination of investment in physical and human capital, knowledge and technical progress. In this aspect, the dynamics of innovative processes may directly impact productivity through complex channels and interconnections that drive the ability of firms to turn R&D efforts into high entrepreneurial profits (Calcagnini et al., 2021).

A standard methodological framework that is used for analyzing the relationship between R&D, innovation, and productivity is the well-known Crepon et al. (1998) (CDM) structural econometric model. In Europe, the estimation of this model is usually based on innovation statistics that are published by Eurostat and are gathered via the Community Innovation Survey (CIS). Interestingly, despite the growing body of empirical studies that analyze the statistics from single waves of CIS (see for example, Mairesse et al.,2005; Benavente, 2006; Griffith et al., 2006; Lööf and Hesmati, 2006; Jefferson et al., 2006; Van Leeuwen and Klomp (2006); Hall et al., 2009; Kijek and Kijek, 2019; Hashi and Stojcic 2013; Ballot et. al 2015), investigations combining multiple years CIS versions have been largely neglected. The potential of longitudinal studies which evaluate the differences between the innovation activities and characteristics between and within countries, to the best of our knowledge, is yet to be exploited. This effectively hinders the application of CIS for developing policies aimed at improving the innovation processs as the resulting analyses do not look at the past behavior of the economies.

To bridge this gap, here we perform a detailed longitudinal analysis on the innovation performance in selected nine European countries by using data for three waves of the survey: CIS 2010, CIS 2012 and CIS 2014. The temporal dimension of our dataset includes periods during the financial crisis as well as the period after the crisis. As such, it allows us to fully evaluate the changes in the innovation processes within the countries during and after the crisis. The countries that are included in the analysis are: Bulgaria, Czech Republic, Germany, Hungary, Norway, Portugal, Romania, Slovakia and Spain. The innovation systems in these countries experience disparities in. terms of the absorption capacity, presence of human capital, quality of the human capital, size of the enterprise, infrastructure, business environment, and size of the local economy, etc.

This allows us to deliver more profound conclusions regarding the structure, innovation strategies and innovation performance of the firms for specific institutional settings in Europe. As such, our contribution can be seen as a generalization to previous studies that explore the relationship between innovation and productivity in a single wave CISs (Tevdovski et al. 2017, Toshevska-Trpchevska et al.2019, Makrevska Disoska 2020).

The analytical framework of the CDM model is consisted of two general stages, while each of them can be divided on two-substages. In the first general stage, we estimate the factors that drive firms' decisions to innovate, as well as innovation investment, using a Heckman correction model. In the second stage, we perform the three-stage least squares (3SLS) methodology to simultaneously estimate the innovation output and the productivity of the firm.

In the first general stage we find that all analyzed factors that drive firms's decisions to innovate have positive and high statistically significant influence. Those are: firms' size, orientation towards national, European or other markets, being part of an enterprise group, having ongoing or abandoned innovations in the previous three years; applying organizational and marketing innovations. Then to measure the innovation input we apply the same explanatory variables as in the first stage, plus we add three dummy variables that intend to determine the influence of three types of subsidies for innovation process. In this stage the results start to differentiate among the countries, and they can be grouped in three categories: the first group are Bulgaria, Romania, Czech Republic and Slovakia; the second group are Germany, Spain and Norway; and Hungary and Portugal are found in the middle, with characteristics of both groups.

In the second general stage we analyze only the firms that have reported innovation activities in the previous stage. The results show that there are great differences among countries on the significance and influence of the analyzed variables over innovation output. In the final stage we measure the influence of firm size, innovation output from the previous stage, and organizational and marketing innovations on labor productivity. The final results show that the impact of the innovation output on labor productivity varies between economies: there is a positive relationship in the more developed economies compared to a negative or neutral relationship in the less developed (though Portugal appears an outliers). We use these results to speculate that the national innovation system in developing economies becomes more vulnerable in periods of financial crises.

The paper is structured into five sections. First, we give brief overview of the competitive position of the Europe on the world market. In the next section we discuss the literature that is relevant to our research. The fourth section describes the data and the methodology used for the creation of the econometric model. Subsequently, the fifth section presents the results obtained from the model. The final section discusses the conclusions from our findings.

2. Background

For Schumpeter (1982), economic growth was related to the innovation of products and the continual development of the existing ones. The extent to which an economy is able to grow depends on both the favorable terms of trade and the degree of specialization in knowledge intensive products with higher value added (Economic Co-operation et al., 1997). These characteristics, in turn, are determined by the ability of the policy makers to develop coherent economic policies which stimulate spending on R&D activities and increase the efficiency of the innovation process. Prior to the development of policies, the policy makers are required to investigate the current and past structural features of the innovation activities, thereby unfolding the innovation system in the economy. A standard micro-approach for performing this step is utilizing cross-sectional microdata capturing the innovation activities of the firms in the country.

United States and the EU are the leading global producers in many knowledge-intensive industries. Overall, the United States is the largest producer of high-technology manufacturing (aerospace and scientific measuring and control instruments) and China is by far the world's largest global producer in medium-high-technology industries. EU comes third and second in these industries. Growth of high and medium technology manufacturing industries in the EU lagged the performance of the United States especially in the post-global recession period. However, the EU is the largest global producer in pharmaceuticals (26%) and second largest global producer in aircraft and spacecraft (22% global share) and testing, measuring, and control equipment (19% global share) (National Science Board, official website). Auto industry in Germany, presented by companies such as: BMW, Mercedes and Volkswagen is the dominant and most resilient industry in Europe.

In commercial knowledge-intensive services (such as banking, finance insurance, R&D services), the United States (31%) and the EU (21%) lead in the volume of world output while China is growing rapidly and now is the third largest producer. Over the last decade, the EU's global share has declined from 29% to 21% due to faster growth in the United States and China and other developing countries.

Despite decades of technological progress, productivity had been growing at a much lower pace in the EU. It is evident that EU is losing its dominant positions on the global market. Although it was expected that membership in EU, will create converges to a unique economic model among countries there are highly different innovation systems in Europe. They vary in terms of institutions, regulatory framework such as intellectual property legislation, (patent and copyright protection), education, employment, quality of human resources, specialization in high and medium tech sectors, financial systems etc. (Pinto and Pereira, 2011).

Although there are different approaches to evaluate the national innovation system, we chose to observe in narrow sense i.e. standard micro-approach. Firms' growth dynamics can help explain differences between countries in aggregate productivity growth (Ark et al, 2008). The paper uses the availability of CIS data in order to explore the link between private and public actors in the production, diffusion and commercialization of knowledge i.e. agents that are directly promoting the generation and use of innovation in national economics.

3. Literature review

Structural econometric framework - CDM model analyzes the relationships among R&D, innovation and productivity. This model was largely used to measure different aspects of the relationship between innovation and productivity. More specifically, the contribution of innovation to productivity (growth) is disentangled into the contribution of R&D input to innovation output - product, process, organizational and marketing innovation, and the contribution of innovation output to the overall productivity.

The creators of the CDM model, Crépon et al. (1998), were among the first ones to explore this relationship empirically and estimated that firm productivity correlates positively with innovation output. Many other studies in this field of expertise conclude that innovation leads to a better productivity performance (Lööf and Hesmati, 2003; Mairesse et al.,2005; Benavente, 2006; Griffith et al., 2006; Lööf and Hesmati, 2006; Jefferson et al., 2006; Hall et al., 2009; Kijek and Kijek, 2019). Hashi and Stojcic (2013) and Stojcic and Hashi (2014) also claim that productivity increases with innovation output although the relationship is stronger in Western European countries compared to Central Eastern European (CEE) countries.

However, there are studies that confirm negative relationship between different types of innovation and productivity (especially when innovation intensity is controlled for). Inverse relationship between process innovation and productivity is estimated in the study of Lööf and Heshmati (2003) for the Swedish firms for the period 1994-1996; Janz et al. (2003) for German firms in the period 1998-2000; Van Leeuwen and Klomp (2006) for the firms in

Netherland for the period 1994-1996; and in the study of Criscuolo, 2009 for 17 OECD countries for the period 2002-2004.

The coefficient for process innovation in Griffith et al. (2006) is negative but statistically non-significant in Spain. Furthermore, Lööf and Heshmati (2006) find a negative relationship between process innovations and productivity in both the manufacturing and the service sector. According to Hall (2011) product innovations create a market power effect that increases the revenue measure of output, whereas efficiency improvements from process innovations may not show up in the revenue figures if they result in lower prices without corresponding increases in output (at least in the short run). Also, the joint effect of product and process innovations is the most visible since they usually go together.

Most recent studies find a negative relationship between innovation output and productivity, and this is especially evident in the CEE countries (Makrevska Disoska et al., 2020 and Toshevska -Trpchevska, 2019) and Southern Europe (Toshevska-Trpchevska et al., 2020). These countries were the most severely hit by the recession and this is affecting the process of convergence in innovation performance in the EU (Archibugi and Filippetti, 2011).

However, despite an abundance of studies that use various versions of the CIS survey and different countries, most of the estimates lie somewhere between these two extremes. The variation in the outcome is a result of wide measurements of the R&D variable and different model specification.

Vancauteren et al., 2017 claims that the productivity (growth) is better explained by R&D if one considers its long-run impact. In the paper of Balcombe et al. (2005) the time-series data for the period 1955-2000 on agricultural innovation, show that R&D is likely to yield productivity improvements over longer time horizons. Raymond et al., 2015 confirm this statement and evidence that continuously undertaken R&D activities in the previous two to four years significantly affect the occurrence and the intensity of product innovations and therefore productivity in French and Dutch firms. However inverse relationship was not demonstrated in their study.

The potential of longitudinal studies which evaluate the differences between innovation activities and characteristics between countries, is yet to be exploited since there is not much done in this area. Bogliacino, 2009 and Bogliacino and Pianta (2009) also highlights the importance of lagged effects on innovation and economic performance with reference to industries (Raymond et. al, 2010) and countries.

Our results confirm the inherent characteristics of the innovation process identified by economic theory. First, the process is dynamic and should be derived from an intertemporal maximization problem. Second, differences in innovation behavior cannot be solely attributed to observable differences across firms (for example, high tech versus low tech). Unobserved heterogeneity, through individual effects, plays a crucial role in accounting for differences in innovation behavior and must be modeled. Finally, qualitative and quantitative measures of innovation (output) must be modeled jointly as they are closely related to one another.

In the recent contribution of Mairesse and Robin, 2017 the authors use CIS data on French firms capturing three different waves of the survey (CIS3, CIS4 and CIS 2008) to assess the measurement errors in the CDM research–innovation–productivity relationships. This paper also uses of the panel of three waves of CIS survey data and assess biases in all three equations of the CDM model and the magnitude of the underlying measurement errors.

4. Methodology and Data

4.1. Methodology

To provide a longitudinal overview of the European national innovation systems, we utilize a modified panel version of the CDM model. Under this model, we first simultaneously estimate the effect of R&D engagement and intensity on innovation outcome and then quantify the effectiveness of the innovative efforts leading to productivity gains for each country separately and account for the temporal property of the data.

Concretely, the developed model controls for the possible time specific effects that may drive the within country differences, such as political and/or economic cycles. Moreover, limited degree of correlation is allowed between the two parts of the model through the inclusion of the inverse Mills ratio in the innovation output equation.

The estimation procedure consists of two general stages which can be divided into two additional sub-stages. In the first stage we implement a Heckman correction model to estimate the innovation input constrained on a variable that models the decision to innovate. Mathematically, this stage can be explained with the following equations.

$$Prob(d_{it} = 1|x_{it}^{0}) = \Phi(\beta_0 x_{0it} + z_{0t}) + u_{0it}, \quad (1)$$

$$w_{it}^{*} = \alpha d_{it} + \beta_1 x_{1it} + z_{1t} + u_{1it}. \quad (2)$$

Equation (1) models the unobserved decision to innovate d_{it} of a firm i in period t as a probit regression (with Φ denoting the cumulative standard normal distribution) dependent on a vector x_{0it} of covariates and their parameter vector β_0. In the equation, z_{0t} is the time-specific that may impact the final decision of the firm of whether to innovate or not. With Equation (2) we estimate the unobserved innovation input w_{it}^{*}, measured as "the log of the amount (in

Euro) of expenditure on intramural or extramural R&D, acquisition of machinery, equipment and software or acquisition of other external knowledge in year of survey", using a vector x_{1it} of covariates, weighted by parameters β_1, adding d_{it} as an additional explanatory variable that helps us to "correct" for the potential selection bias which arises due to using only data for firms that decided to invest in innovation and again including a time-specific effect z_{1t}.

The second stage utilizes the three-stage least squares (3SLS) methodology to simultaneously estimate the innovation output and the productivity of the firm. This stage is specified as

$$r_{it} = \beta_{w^*} w_{it}^* + \beta_q q_{it} + \beta_2 x_{2it} + z_{2t} + u_{2it}, \quad (3)$$

$$q_{it} = \beta_r r_{it} + \beta_3 x_{3it} + z_{3t} + u_{3it}. \quad (4)$$

In equation (3) r_{it} is the innovation output measured as "the logarithm of the firm's percentage of turnover in year of survey coming from goods or services that were new to market or to enterprise in 3 years prior to survey", z_{2t} is the time-specific effect and u_{2it} is the error term. Together with this equation we estimate equation (4) – the productivity q_{it} of the firm, "quantified as the log of the firm's turnover divided by number of employees in year of survey", as a linear function of the innovation output r_{it} and a vector of exogenous explanatory variables x_{3it} with parameter vector β_3. As in the previous equations, z_{2t} is a time-specific effect and u_{3it} is the error term.

4.2. Data

We implement our econometric model on firm level data taken from three waves of the Community Innovation Survey (CIS) for 9 countries. The CISs represent harmonized surveys aimed at collecting microdata on innovation activities conducted in a period of two years from enterprises belonging to countries that are part of the Eurostat network. In this analysis we utilize three waves of CIS surveys, namely CIS10 (conducted between 2008-2010), CIS12 (conducted between 2010-2012) and CIS14 (conducted between 2012-2014) for Bulgaria, Czech Republic, Germany[1], Hungary, Norway, Portugal, Romania, Slovakia and Spain. We create unbalanced panel samples for every country, i.e., for each country we have data for three different periods but the set of firms in each period is not necessarily the same. The detailed description of the used variables in the model is presented in the table A1 in the Appendix, while table A2 presents the summary statistics of the innovation and productivity variables included in the analysis for every country during the three periods. It can be easily noticed that there are significant discrepancies in the observed average values of the variables that are included in the analysis between the countries, therefore suggesting that the innovation process is not the same between countries.

5. Interpretation of the results

In this section we interpret the results in four sub-sections corresponding to the four stages of the model and separately by each country.

5.1. Decision to innovate

The first stage of the CDM model gives results on the factors that drive firms' decisions to innovate. It models the decision to innovate as a function of: firm size measured as natural logarithm of employment; three dummy variables for market orientation, representing the presence of the firm on national, EU or/and other markets; a dummy variable for a firm being part of an enterprise group; a dummy variable for a firm having ongoing or abandoned innovations in the previous three years; and, two dummy variables for a firm undertaking organizational (introduced new or improved knowledge management system, changed management structure, integrated different activities or introduced changes in its relations with other enterprises or public institutions) or marketing innovation (introduced significant changes to packaging of goods or services or changed its sales or distribution methods) in the previous three years. The results are given in Table 1.

[1] The CIS10 dataset does not include reliable data for Germany, and therefore only for this country the dataset is constituted of combining the CIS12 and CIS14 dataset.

Table 1. Decision to innovate

VARIABLE	Bulgaria	Czech Rep.	Hungary	Romania	Slovakia	Germany	Spain	Norway	Portugal
Firm Size	0.183***	0.156***	0.192***	0.093***	0.131***	0.184***	0.015***	0.049***	0.206***
Market participation									
National	0.249***	0.243***	0.202***	0.185***	0.122**	0.310***	0.376***	0.317***	0.164***
European	0.271***	0.211***	0.146***	0.087***	0.255***	0.389***	0.231***	0.430***	0.195***
Other	0.233***	0.338***	0.259***	0.322***	0.340***	0.438***	0.430***	0.411***	0.214***
Part of a group	0.134***	0.164***	0.110***	0.169***	0.238***	0.241***	0.197***	0.010	0.075***
Abandoned or ongoing innovations	3.712***	2.542***	8.113***	7.585***	6.979***	0.704***	0.712***	1.997***	2.881***
Innovations									
Organizational	0.778***	0.861***	0.885***	0.776***	1.004***	0.477***	0.687***	0.671***	0.909***
Marketing	0.648***	0.886***	0.699***	0.697***	0.863***	0.430***	0.534***	0.887***	0.832***
Observations	39,039	15,555	15,783	24,308	7,718	11,806	96,082	15,076	18,076

*** p<0.01, ** p<0.05, * p<0.1

The results confirm the fact that the probability a firm to engage into the innovation process increases with its size. Firms with more employees have higher probability to engage into the innovation process in all nine countries. However, the sizes of the estimated coefficients show that increase of the firm size have different marginal effect on the probability to innovate across countries. It is highest in Hungary and Portugal, while lowest in Norway and Spain.

The results also confirm the fact that the intensity of competition motivates firms to innovate. Firms that are oriented towards national, EU and other foreign markets are more likely to innovate than firms oriented towards local/regional markets. The participation of all surveyed countries in the joint EU market may be explanation for not existence of the differences in the decision to innovate between national and EU market. Firm being a part of enterprise group increases the probability to innovate in all surveyed countries, except in Norway, while the marginal effect of this influence is strongest in Germany. From political economy perspective, based on the Hall and Soskice typology, this can be explained by the existence of the coordinated market economy which poorest form is in Germany. The results also show that existence of innovation process in a current or past period increase the probability to innovate in all countries. The high values of the coefficients for this explanatory variable implies that persistence is important for the decision to innovate, showing also that a firm needs to achieve some level in order to enter in innovation activities and that acquired knowledge is important.

At the end, the firm's decision to innovate in all countries is influenced by organizational or marketing innovations. The probability of an innovation decision increases with improvements in management system, changes in management structure, changes in its relations with other firms and institutions, changes in packaging of goods or services or changes in distribution methods.

5.2. Innovation input

In the second stage of the model, we analyze the innovation input that represents innovation expenditure measured by the natural logarithm of the overall amount spent on innovations in a firm. We are modeling innovation input by the same explanatory variables as in the first stage, plus we add three dummy variables that intend to determine the influence of subsidies for innovation process. The three different sources of subsides received by a firm are observed: local, national and EU level.

The results are presented in Table 2. As expected, investment in innovation increases with firm's size in all observed countries, except in Romania. The marginal effects of the firm size for innovation investment is different across countries. It is highest in Germany and lowest in Spain.

Firms that are oriented towards national, EU and other foreign markets in general invest more in innovation than firms oriented towards local/regional markets, but there are exceptions. Firm orientation to national market or EU market does not increase innovation investment in Czech Republic, Romania and Slovakia, while in Bulgaria only orientation to national market. Also, firm orientation to other markets outside to joint EU market is important for the firms in all countries, except in Romania. One possible explanation for these results can be the situation that R&D activities are not made in many firms operating in Bulgaria, Czech Republic, Romania and Slovakia, but in their mother firms or headquarters outside of the borders of these countries. Also, this argument for Bulgaria and Czech Republic is confirmed by the significant coefficient in front the variable for the firm being part of enterprise group. Investment in innovation is higher in firms which are part of groups in all countries, except in Romania and Slovakia. Similarly, persistence in investment in innovation is increasing innovation input in all countries, except in Hungary, Romania and Slovakia. The presence of the organizational innovations is increasing innovation investment in all countries, except in Romania, while the marketing innovations does not have importance in firms in the three countries (Hungary, Romania and Slovakia) that have not persistence in innovation investment. This result suggests that investment in marketing in these three countries is not made in parallel with more innovation investment.

In terms of funding, local subsidies have positive and significant effect on investment in innovation only in Hungary, Germany, Spain, and Norway, while national and EU subsidies increase innovation input in all countries. One possible explanation for these results can be low level or not existence of local subsidies for the innovation activities in Bulgaria, Romania, Czech Republic, Slovakia and Portugal.

Table 2. Innovation inputs

VARIABLE	Bulgaria	Czech Rep.	Hungary	Romania	Slovakia	Germany	Spain	Norway	Portugal
Firm size	0.409***	0.329***	0.268***	0.012	0.338***	1.210***	0.024**	0.132***	0.342***
Market participation									
National	-0.011	0.085	-0.445***	-0.081	-0.138	0.170**	0.335***	0.231***	0.217***
European	0.197**	0.059	0.257**	0.164	0.085	0.207***	0.124***	0.488***	0.101*
Other	0.470***	0.497***	0.347***	0.085	0.441***	0.406***	0.297***	0.633***	0.153***
Part of a group	0.548***	0.386***	0.395***	0.287	0.136	0.771***	0.434***	-0.146**	0.398***
Abandoned or ongoing innovations	1.547***	0.234***	0.266	-0.788	0.165	0.272***	0.527***	0.419***	0.155**
Innovations									
Organizational	0.717***	0.350***	0.373***	-0.11	0.423**	-0.480***	0.362***	0.290***	0.352***
Marketing	0.370***	0.221***	0.179	-0.314	0.179	-0.123*	0.265***	0.125*	0.164***
Funding									
Local	0.285	0.175	0.883***	0.063	-0.251	0.640***	0.571***	0.297***	0.105
National	0.742***	0.851***	0.797***	1.006***	0.863***	0.703***	1.069***	1.027***	0.804***
EU	1.044***	0.713***	1.048***	1.004***	0.826***	0.815***	0.878***	0.851***	0.771***
Observations	39,039	15,555	15,783	24,308	7,718	11,806	96,082	15,076	18,076

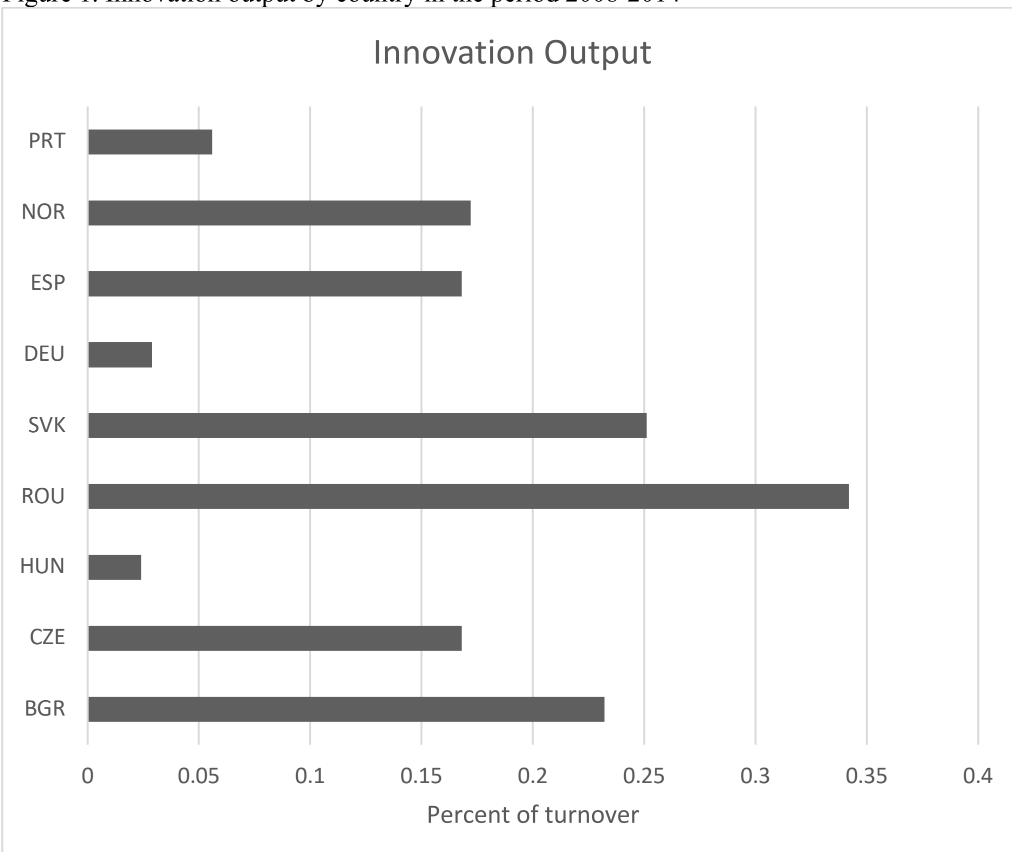
*** p<0.01, ** p<0.05, * p<0.1

The results across all explanatory variables differentiate two groups of countries regarding the investment in innovation. In the first group are Bulgaria, Romania, Czech Republic and Slovakia, while in the second group are Germany, Spain and Norway. Hungary and Portugal are found in the middle, with characteristics of both groups. The first group consists of the new EU member countries. According to the varieties of capitalism argument, the countries in the first group belongs in the dependent market model (Nolke and Vliegenhart, 2009). It is the third typology of capitalism that emerge in the post-communist countries, where firms are managed through hierarchy within transnational corporations and they are used mostly as assembly platforms, while innovations are made in headquarters outside their territories and transferred within transnational corporations' hierarchy. On the other side, for firms in the second group most of the analyzed variables are significant and have positive influence over the innovation investment.

5.3. Innovation output

In the third and fourth stage of the model we analyze only the firms that have reported innovation activities in the second stage. This is the reason for the decreased number of observations in comparison with the previous two stages. In this stage, we measure the innovation output i.e. the results from the innovation activities undertaken by the firms. More precisely innovation output is natural logarithm of the share of sales of new products and services (new to the firm and new to the firm's market) in the total turnover of the company. The summary statistics of the innovation output per country in the analyzed period is presented in Figure 1. The data in the graph show that innovation output is higher in the countries from new EU members group rather that the old EU members. The three countries with highest innovation output are Romania, Slovakia and Bulgaria. This can be explained by the productivity gap in the firms from new EU member countries in comparison with the firms from old EU members.

Figure 1. Innovation output by country in the period 2008-2014



In third stage, we measure the impact of firms' size, innovation input from the second stage, natural logarithm of firms labor productivity, organizational and marketing innovations, and funding (from local authorities, the national government or EU) on the innovation output. In Table 3 we present the results of the third stage of the model. The data show that there are great differences among countries on the significance and influence of the analyzed variables over innovation output. In this stage we also included the inverse Mill's ratio, calculated from the first stage of the model, to control for potential selectivity bias. The coefficient of Mill's ratio is significant at 1% in the case of Slovakia, Germany and Spain. The insignificance of the Mill's ratio for the rest of the countries is suggesting the absence of selectivity.

The estimated coefficients on firms' size point out that in six of the analyzed countries (Czech Republic, Hungary, Germany, Spain, Norway and Portugal) there is significant and negative effect of firms' size over innovation output. This means that bigger firms are less efficient than smaller firms in converting the innovation input to innovation output, i.e. the marginal effect of the innovation input is lower in smaller firms than in bigger firms. This finding we have also discovered in our previous analysis (Toshevska-Trpchevska, et al., 2020), where the focus in only on CIS2014 and it is in the line with stylized observations first documented by Cohen and Clepper (1996). Vyas and Vyas (2019) explained this negative effect of firms' size on innovation output by the increasing influence of entrepreneurs and small firms in innovation in modern economies. We note that for the other three analyzed countries, the firms' size is not significant for the innovation output but for two of them (Bulgaria and Slovakia) it is also with negative sign.

We find positive and statistically significant relationship between innovation input and output in six out of nine countries. Romania is the country with highest marginal effect of the innovation input, where 1% increase in innovation investment would yield to 0.787 increase in innovation output. In the analyzed period, we observe negative marginal effect of innovation input only in Bulgaria and Spain.

The effect of labor productivity on innovation output is significant on 1% level only in three countries, while in two of them (Romania and Portugal) is negative. Negative relationship between labor productivity and innovation output implies that more efficient firms have a lower proportion of sales from new products in their total revenue. The same finding was previously documented by Hashi et al. (2013) for the sample of Central and Eastern European countries using CIS4. They explained it by possibly risk-aversion of more efficient firms in these countries, arguing that the introduction of new products or services increases the risk of failure which is why these firms transform improvements in efficiency into competitive advantages in the production of existing products. Another complementary explanation can be found in the variety of capitalism typologies, where the firms in the Dependent market model does not innovate, but are used as production platforms, based on cheap labor. Contrary to this finding is situation in Norway, where the effect of labor productivity on innovation input is significant and positive.

Table 3. Innovation output

VARIABLE	Bulgaria	Czech Rep.	Hungary	Romania	Slovakia	Germany	Spain	Norway	Portugal
Firm size	-0.021	-0.224***	-0.326***	0.001	-0.183	-0.767***	-0.110***	-0.363***	-0.172***
Mills's ratio	-0.735	0.353	-2.506*	1.585	5.042**	0.683**	-0.857**	0.294	0.192
Innovation input	-0.387***	0.220**	0.353*	0.787*	0.588*	0.417***	-0.475**	0.254***	0.210
Labor productivity	-0.002	0.056	-0.367*	-0.776***	0.086	0.001	0.043	0.300**	-0.467***
Innovations									
Organizational	0.476***	0.095**	-0.201	0.527**	0.837***	0.458***	0.135***	-0.111*	0.146***
Marketing	-0.004	-0.075*	-0.22	0.464*	0.688**	0.031	0.130***	0.132**	-0.095**
Funding									
Local	0.431**	-0.089**	-0.09	0.109	0.366	-0.175***	0.344**	0.049	-0.059
National	0.516***	-0.191**	-0.314	-0.583	-0.274	-0.297***	0.571**	-0.114	-0.159
EU	0.309**	-0.181**	-0.430*	-0.823*	-0.363	-0.172***	0.501**	-0.079	-0.169
Observations	3,199	3,586	1,502	683	565	2,224	11,363	2,893	3,832

*** p<0.01, ** p<0.05, * p<0.1

The organizational innovations are statistically significant and positive in most of the countries, except in Norway. This implies that firms in these countries can achieve higher sales from new products by improvements in organizational efficiency. The results with respect to marketing innovations are rather ambiguous. The effect is positive only in four countries (Slovakia, Spain, Norway and Romania), suggesting that differentiation in terms of design, packaging or delivery can enable firms to achieve higher sales from new products.

Regarding funding, we find statistically significant and negative effect of subsidies from different levels on innovation output in many cases. These results question the ability of existing subsidies to adequately support innovation process. On the other side, Bulgaria and Spain are two countries with positive effects of subsidies from all three levels (local, national and EU) on innovation output.

5.4. Labor productivity

In the final stage of the model, we estimate the effect of firm size, innovation output from the third stage, and organizational and marketing innovations on labor productivity. Exploring the relationship between innovation and productivity has been main driving force of the CDM model and motive for many researches in this field. Although most of the conducted analyzes have found the positive relationship among innovation and labor productivity there are also studies that documented negative relationship. In this paper we try to analyze the innovation – productivity relationship through longitudinal perspective and diagnose potential problems with certain countries and their national innovation systems. In Figure 2 we present the summary statistics of labor productivity by each country in the whole period. The graph shows that highest labor productivity has been recorded in Germany, while the lowest level in Romania and Bulgaria.

Figure 2. Average labor productivity per country in the period 2008-2014

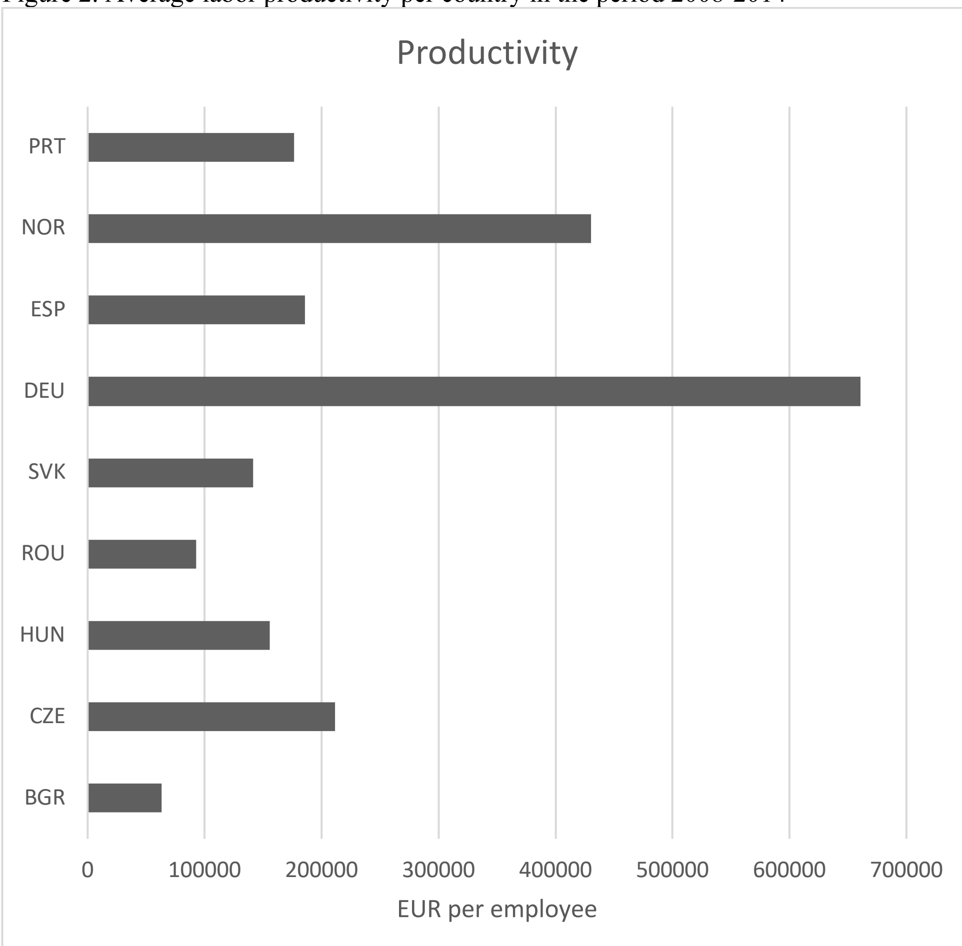


Table 4. Labor productivity

VARIABLE	Bulgaria	Czech Rep.	Hungary	Romania	Slovakia	Germany	Spain	Norway	Portugal
Firm size	-0.030	0.516**	1.642	0.177***	0.235***	0.936***	-0.173**	0.120**	-0.384**
Innovations									
Organizational	0.430***	-0.192	-1.189	0.194*	0.265	-0.625***	0.149*	0.128***	0.558***
Marketing	0.01	0.237	-0.344	0.093	0.237*	-0.043	0.177**	-0.004	-0.236*
Innovation output	-0.642*	2.248	7.313	-0.066	-0.558	1.868***	-2.970***	-0.229	-3.034***
Observations	3,199	3,586	1,502	683	565	2,224	11,363	2,893	3,832

*** p<0.01, ** p<0.05, * p<0.1

We present the estimated results from the fourth stage of the model in Table 4. The size of the firm has positive and significant effect over labor productivity in the case of Czech Republic, Romania, Slovakia, Germany and Norway. This means that in these countries the same level of innovation output has larger impact on productivity in larger firms than in smaller firms. The coefficients are significant but with negative sign in Spain and Portugal which implies that in these countries the same level of innovation output has smaller impact on productivity in larger firms.
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The effect of innovation output is positive and significant only in the case of Germany and Spain, where is confirmed that firm's productivity increases with innovation output. On the other side are Bulgaria and Portugal, where the effect of innovation output is significant but with negative sign. This implies that with more innovation output does not lead to higher labor productivity. These results are in line with our previous studies. We found negative relationship between innovation output and productivity for Central and Eastern European countries in 2010, 2012 and 2014 and for Southern European countries (Spain, Portugal and Greece) in 2014 (Toshevska-Trpcehvska, et al., 2019, Makrevska Disoska, et al., 2020, Toshevska-Trpcehvska, et al., 2020). For the other countries' innovation output is not significant for labor productivity in the analyzed period.

As expected, the organizational innovations have significant and positive effect on labor productivity in most of the analyzed countries. In contrary, the effect of marketing innovations is insignificant in the case of six out of nine countries.

6. Conclusion

In this paper we provide longitudinal analysis of different types of innovations and their influence over labor productivity in selected nine European countries for the period of six years (2008-2014). In the analyzes we have representatives which are highly developed countries (Germany as EU old member and Norway), some which had problems with the macroeconomic stability in the aftermath of the financial crisis (Spain and Portugal) and representatives from the new EU member countries from Central and Eastern Europe (Bulgaria, Czech Republic, Hungary, Slovakia, and Romania). The application of the four-stage CDM model enabled us to see and differentiate the influence of different variables among different national innovation systems during longer time period.

This four stages model has led us to gradually observe the determinants of the innovation process and their influence over increasing labor productivity. We found that the factors that drive firms' decision to innovate are almost the same among all analyzed countries. These results indicate that all analyzed variables are significant and have positive relationship with the companies' decisions to start to innovate. In the next stage the results start to differentiate. For Bulgaria, Czech Republic, Hungary, Germany, Spain, Norway and Portugal almost all of the analyzed variables (with rare exceptions) have statistically significant and positive influence over innovation input. For Romania and Slovakia, most of the analyzed variables are insignificant for innovation input. The differences start to increase in the following stages and the countries can be grouped into three groups. For Germany and Norway most of the variables have positive and significant influence over innovation output; for Spain and Portugal the results are mixed: there are variables that have positive and significant influence over innovation output, but also there are variables that have significant but negative influence. For the other five analyzed countries the results show that most of the variables are either insignificant or significant but with negative sign. Only few variables are positive and significant for the increasing innovation output in the group of "new" EU member countries.

The most important result from the analysis comes from the last stage where we test the influence of innovation over productivity. Once again, the results in this paper confirm the findings from our previous research. The positive impact of innovation over productivity is confirmed only in Germany as highly developed economy with stable national innovation system. In all the other countries we have found either insignificant (in CEE countries) or significant and negative influence (Spain and Portugal) of innovations over labor productivity. This indicates that the national innovation systems of these countries appear to be vulnerable and cannot properly transfer innovation into increase of productivity. In this aspect, we believe that there is an urgent need of reconstruction of the national innovation systems in these countries. In order to obtain a more precise explanation of the problems of the national innovation systems and offer a possible solution for reconstruction a more detailed analysis is needed, taking into consideration the specific situation and conditions in separate countries. This might be a sufficient challenge for future research in this area.

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Appendix

Table A1. Definition of variables

Dependent variables	Definition
Eq. (1): Decision to innovate	Dummy variable; 1 if firm in 3 years prior to survey engaged in intramural or extramural R&D, purchased new machinery, equipment, software or other external knowledge, engaged in training of personnel, market research or did any other preparations to implement new or significantly improved products and processes
Eq. (2): Innovation input (natural logarithm)	Amount (in Euro) of expenditure on intramural or extramural R&D, acquisition of machinery, equipment and software or acquisition of other external knowledge in year of survey.
Eq. (3): Innovation output (natural logarithm)	Percent of firm's turnover in year of survey coming from goods or services that were new to market or to enterprise in 3 years prior to survey
Eq. (4): Labor productivity (natural logarithm)	Turnover divided by number of employees in year of survey
Independent variables	
Firm size (natural logarithm)	Number of employees
Market participation	
National market	Dummy variable; 1 if firm in past 3 years sold goods on national market
EU Market	Dummy variable; 1 if firm in past 3 years sold goods on EU, EFTA or EU candidate countries markets
All other countries	Dummy variable; 1 if firm in past 3 years sold goods on markets of other countries
Part of a group	Dummy variable; 1 if firm is part of an enterprise group
Abandoned or ongoing innovations	Dummy variable; 1 if firm in past 3 years had any abandoned or ongoing innovations
Organisational innovation	Dummy variable; 1 if firm in past 3 years introduced new or improved knowledge management system, changed management structure, integrated different activities or introduced changes in its relations with other enterprises or public institutions (alliances, partnerships or subcontracting)
Marketing innovation	Dummy variable; 1 if firm in past 3 years introduced significant changes to packaging of goods or services or changed its sales or distribution methods
Funding	
Local	Dummy variable; 1 if firm in past 3 years received financial support for innovation activities from local/regional authorities
Government	Dummy variable; 1 if firm in past 3 years received financial support for innovation activities from central government
EU	Dummy variable; 1 if firm in past 3 years received financial support for innovation activities from EU authorities
Inverse Mill's ratio	Inverse Mill's ratio from selection equation

Table A2. Summary Statistics (Average values of the variables)

VARIABLE	Bulgaria	Czech Rep.	Hungary	Romania	Slovakia	Germany	Spain	Norway	Portugal
Decision to innovate	0.177	0.477	0.265	0.129	0.227	0.553	0.336	0.388	0.545
Firm size	66.866	140.855	110.575	145.183	142.044	211.897	112.072	104.717	89.893
Market participation									
National	0.495	0.766	0.878	0.574	0.739	0.691	0.744	0.64	0.802
European	0.364	0.602	0.636	0.387	0.566	0.44	0.428	0.364	0.56
Other	0.168	0.261	0.293	0.148	0.183	0.337	0.281	0.261	0.418
Part of a group	0.161	0.371	0.311	0.146	0.347	0.388	0.301	0.767	0.278
Abandoned or ongoing innovations	0.014	0.08	0.04	0.01	0.03	0.157	0.094	0.093	0.076
Innovations									
Organizational	0.119	0.291	0.173	0.172	0.184	0.342	0.29	0.265	0.37
Marketing	0.127	0.277	0.177	0.159	0.163	0.319	0.19	0.254	0.361
Funding									
Local	0.002	0.019	0.004	0.004	0.003	0.069	0.084	0.024	0.017
Government	0.021	0.098	0.055	0.011	0.015	0.15	0.096	0.066	0.125
EU	0.028	0.091	0.065	0.011	0.023	0.064	0.026	0.008	0.06
Labor productivity	63203.518	211427.62	155732.57	92922.204	141462.91	660916.23	185584.86	430315.68	176385.51
Innovation input	33426.562	502106.49	1.90E+08	61498.517	260606.26	15911171	259858.95	1482003.2	173518.52
Innovation output	0.232	0.168	0.024	0.342	0.251	0.029	0.168	0.172	0.056