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Differences in innovation relationships between Central and Eastern Europe and Western Europe: Evidence from CIS 2014

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Abstract

The existence of complementarity between different types of innovations is important in the decision to continue innovating in terms of absorbed synergies and capacities generated by the firm and through economies of scale to have positive effect over increasing productivity. In this paper we explore the complementarity and substitutability relationships between different innovation activities by utilizing cross-sectional data taken from the Community Innovation Survey - CIS2014 for two groups of countries: Central and Eastern Europe (CEE - Bulgaria, Croatia, Hungary, Romania, and Slovakia) and Western European countries (WE - Greece, Spain, Norway and Portugal). We analyze the interactions between four different types of innovation: 1) firm innovation, 2) market innovation, 3) organizational innovation, and 4) process innovation with data from the period 2012-2014. The results indicate that all types of innovation have statistically significant and positive impact on the productivity in the companies operating in both, Central and Eastern European and Western European markets. However, our findings suggest that the relations between different innovation pairs have a substitute nature. We rationalize our results by conducting a robustness analysis for each country separately and we discovered a wide range of different complementary relationships. These relationships are dependent on the underlying country that is subject of the analysis.

Keywords: innovation, complementarity, substitutability, Central and Eastern Europe, Western Europe.

JEL Codes: O31, O33.

1. Introduction

Productivity is closely related to technological innovation. However, simple adoption of technological innovations alone is not sufficient to increase productivity. The technological benefit can be achieved if they are accompanied by a cluster of related innovations in production, organization, customer and supplier relationships and new product design (Ruigrok et al., 1999). That means that firms that combine organizational innovation with product and process innovation can achieve higher profit margin (Schmidt and Rammer, 2007). The academic literature emphasizes the effectiveness of management practices of the companies on productivity level (Porter and Ketels, 2003; Bloom and Van Reenen, 2007).

This paper explores the relationship between product, process, and organizational innovations and the effects on economic performance when combining these innovation activities. The aim of this paper is to determine whether firms gain more benefit by undertaking different forms of innovation simultaneously than by undertaking the same forms of innovation separately. The options can be pure technological innovation strategy or organizational restructuring. Instead of exploring the effect of technological and organization innovation separately (see for example Damanpour (2014) and Battisti and Stoneman (2010)), we investigate the joint effects of different types of innovation. However, there are many obstacles in the way of the diffusion process of innovations - and not primarily by patents, plant secrets etc., but much more significant impediments to be found in the nature of the diffusion process itself. Therefore, the presence of complementarities depends on the national context as well as on firm size and firm capabilities.

We test for complementarity by adapting a supermodularity (complementarity) and submodularity (substitutability) framework and proxying performance by sales per employee. Our approach builds on techniques developed in Athey and Stern (1998) and utilized in Mohnen and Roller (2005) and Doran (2012). The same model is implemented by Leiponen (2005), Cassiman and Veugelers (2006), Ballot et al. (2015). For the empirical analysis we use data from the Community Innovation Survey - CIS2014 on 9 countries. The difference between our approach and other contributions is that we divide the countries into two sub-samples: Central and Eastern European countries (CEE) comprising: Bulgaria, Croatia, Hungary, Romania and Slovakia and Western European countries (WE) comprising: Greece, Spain, Norway and Portugal. The division has been done as a continuation of our previous research on differences among the functioning and the influence of the innovation systems over productivity among the new member countries and the old European Union member countries. The selection of the countries included in this analysis is done according the available data from the CIS 2014 dataset. With the latest dataset from Eurostat we have obtained complete data for only these nine countries. So, nevertheless, we decided to divide the countries into these two groups according the same logic: Central and Eastern European countries that have been part of the European single market since 2004 and Western European countries that have been part of the European single market long before 2004.

Our results indicate that all innovation combinations have statistically significant and positive impact on the productivity in the companies operating in both, Central and Eastern European and Western European markets. However, the relations between different innovation pairs have a substitute nature. To justify our results, we conduct a robustness analysis for each country separately and discover a wide range of different complementary relationships. That is, there are countries in which there are solely complementary relationships between innovation types and countries in which the substitute nature prevails. As a result, we hypothesize that the relationships between innovations are dependent on the underlying country that is the subject of the analysis. The implications created by our work can be used for prospectus development of the national innovation systems and assist firms to choose the proper strategy for improving their economic performance.

The rest of the paper is structured as follows. In Section 2, we provide a detailed literature review on the studies which explore the relationship between different types of innovations and their effect over productivity. In Section 3, we describe the empirical model and elaborate the data used for our analysis. In this section, we also explain the theoretical background of the model applied, the possible interactions between different types of innovations, and the estimation setup. In Section 4 paper, we present the results from the empirical analysis procedures, separately for the productivity function, and separately for the differences in the innovation relationships. In the last section, we summarize our findings.

2. Literature review

The focus of this paper is to explore the relationship between four types of innovations: new to market innovation (product innovation), new to firm innovation (product innovation), process and organizational innovation. The idea is a result of previously made studies on determining the links between R&D engagement, R&D intensity, innovation output and productivity in selected Central and Eastern European Countries and Western European Countries (Tevdovski et al, 2017; Toshevska-Trpchevska 2019; Makrevska Disoska et al., 2020; Toshevska-Trpchevska et al. 2020; Makrevska Disoska et al, 2021;). Similar studies related to this topis are: Loof and Heshmati (2006), Janz et al. (2004), Parisi et al.(2005), Johansson and Loof (2009), Griffith et al. (2006); Hashi and Stojcic (2013) and Stojcic and Hashi (2014).

Tevdovski et al. (2017) estimate two output production function for Bulgaria, Romania and Germany separately for two types of innovations (one for process and product innovation and second for organizational and marketing innovations) due to the existence of high correlations between innovations. The results measuring the output production function on marketing and organizational innovation indicate that in these countries innovation may lead to increasing labor productivity through introducing organizational changes. Introducing marketing changes appears to be less important and not cost efficient for improving labor productivity. Polder et al. (2009) also claim that product and process innovations affect productivity only if accompanied by organizational innovation, in both services and manufacturing sectors. This suggests that the probability of an innovation decision increases with the introduction of new business practices, new methods of organizing work responsibilities, new methods of organizing relations with clients and suppliers and other. On the other hand, both organizational and marketing innovations have a positive impact on the probability of European SMEs decision to engage in process or product innovation in the study of Disoska and Toshevska-Trpchevska (2019).

However, many authors go further in determining complementarity or substitutability among different types of innovations in the knowledge augmented production function. The nature of the relationship between different types of innovations can go in two directions: technological innovations and non-technological innovations. Technological innovations or complementary relationship between product and process innovation is confirmed in the studies of Martinez-Ros and Jose M. Labeaga (2009) and Miravete and Pernias (2006). Some authors confirm complementarity relationship between different types of innovations such as the studies of Schmidt and Rammer, 2007 and Mol and Birkinshaw, 2009). They confirmed close relationship between product innovation and organizational innovations.

However, there are mixed findings regarding the technological or non-technological innovations when analyzing innovation pattern in different countries. Ballot et al., 2015 find that conditional complementarity exists between product and process innovations in French and UK firms and between organizational and product innovations in French firms, but no complementarity between all three forms of innovations. Berulava and Gogokhia, 2018 also reveal that complementarity exists between product and process innovation and also between process and non-technological innovations (marketing and organizational innovation) in transition economies, on the basis of BEEPS V dataset and using extended Crépon-Duguet-Mairesse model (CDM). Reichstein and Salter (2006) showed that process and product innovations are interdependent, and its relationship should be seen as 'brothers' rather than 'distant cousins'.

Doran, 2012 provided empirical evidence that among six possible innovation combinations none exhibits signs of subsidiarity for Irish firms using CIS04. Combining product and process innovation increases new product export intensity in Poland (Lewandowska, et al, 2016). The work of Carboni, O. A.,and Russu, P. (2018) uses a sample of firm-level data from seven EU countries (Austria, France, Germany, Hungary, Italy, Spain and the United Kingdom) using dataset (European Firms in a Global Economy). The results support the hypothesis that the three types of innovations (process, product, and organizational innovations) are interdependent.

The existence of complementarity between different types of innovations is important in the decision to continue innovating in terms of absorbed synergies and capacities generated by the firm (Martinez-Ros and Labeaga, 2009). Engaging into complementary innovation activities can increase the gain through economies of scale and enhance its market image. That will have positive effect on increasing productivity.

3. Model and data

3.1.Theoretical background

We assume that the output Y_i of firm i is a result of a Cobb-Douglas-esque production which takes the following functional form

$$Y_i = A_i L_i^{\alpha} C_i^{\beta}, \tag{1}$$

where, L_i is the labour input, C_i is the capital input and, α and β are, respectively, their marginal elasticities. In the equation, A_i denotes the *total factor productivity*.
The corresponding regression form of Eq. (1) is derived by first dividing the equation with the labor and then taking the natural logarithm. The result is

$$y_i = (\alpha + \beta - 1)\, l_i + \beta\, c_i + w_i + e_i, \tag{2}$$

where $y_i = \log \frac{Y_i}{Li}$ is the log of the output per employee, l_i is the log of the labor and c_i is the log of the capital input per employee, $c_i = \frac{C_i}{L_i}$. The log of the total factor productivity is divided into two components: 1) w_i that describes the observed factors that affect productivity and directly impact the output of a firm, and 2) e_i, i.e., the unobserved factors that affect productivity and directly translate to the output of the firm.

We follow standard literature and assume that the equation for w_i can be written as

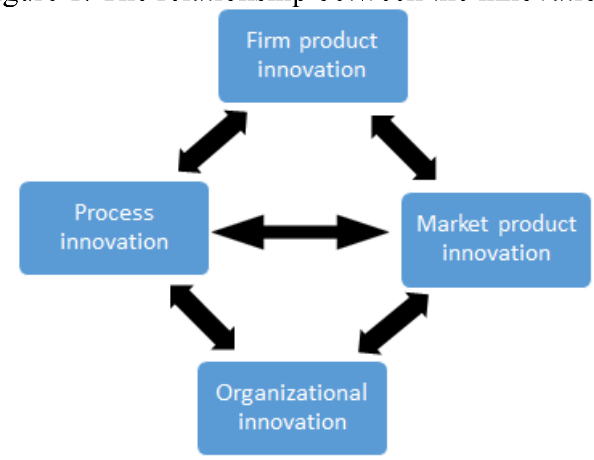
$$w_i = \lambda h_i + \delta r_i + \sum_k \gamma_{ik} x_{ik}.$$

That is, we presume that the observed factors that affect productivity are human capital h_i (λ is its marginal effect) and the effect of research and development r_i(δ is its marginal effect). Besides these two variables, we also suppose that there is a set of K innovation types present in the firm. In total, there are a total of 2^K different combinations of interaction between the different types of innovation. Each interaction may impact differently the total factor productivity, and hence the output of firms' innovation. In our specification, the k-th interaction is defined as an indicator variable and it is labeled x_{ik}, with γ_{ik} being its marginal effect. In what follows we describe in detail the different types of innovation and their possible interactions.

3.2. Interactions between innovation types

We identify four different types of innovations, and hence, 16 different interactions between innovation types. Fig. 1 summarizes the potential interactions between the innovation types. The types of innovation are: 1) firm innovation, 2) market innovation, 3) organizational innovation, and 4) process innovation. A *firm innovation* occurs when the firm began producing a new product or service to that was previously not made by them, but it was present on the market. The firm produces a *market innovation* when it introduces an entirely new product or service to the market. *Organizational innovation* happens when the firm introduces new business practices for organizing procedures, new methods of organizing work responsibilities and decision making or new methods of organizing external relations. Finally, a *process innovation* appears when the firm introduces a new or significantly improved method of production, a new or significantly improved logistic, delivery or distribution system or new or significantly improved supporting activities.

Figure 1. The relationship between the innovation types



Source: Authors' illustration.

Two innovation types, A and B, can be either complements or substitutes. Complementary relationship occurs when the effect of the joint presence (or absence) of both innovation types on the output is larger than the presence of only one of them. Mathematically this can be written as:

$$I(AB) + I(\emptyset) > I(A) + I(B),$$

Where $I(AB)$ is a variable quantifying the impact on the output of the firm if both A and B are present within the firm, $I(\emptyset)$ is a variable describing impact of the absence of both innovation types, $I(A)$ is the marginal effect on the output if innovation type A is present in the firm, and analogously $I(B)$ is the marginal effect only on the output only if innovation type B Is present.

In contrast, a substitute relationship appears simply when reversing the inequality in the equation, i.e.,

$$I(AB) + I(\emptyset) < I(A) + I(B) .$$

In words, this appears when it is more profitable for the firm to focus on innovating only one of the two types of innovations.

Taking into account many previous studies that identify positive relationship among process and product innovations, meaning that firms that engage in process innovation are more likely willing to engage into product innovation, we decided to elaborate the relationship among products and process innovation taking into account the degree of novelty. Since there are two types of product innovation, new to firm and new to market innovation, we considered that the strengths of the complementarity relationship could be measured separately, for new to firm and new to market innovation. It is expected that new to market innovation would be more novel innovation that new to firm innovation (OECD, 2005). Based on this we propose the first two hypothesis: H1 and H2.

H1: New to firm product innovation and process innovation complement one another in firms' production functions.

H2: New to market product innovation and process innovation complement one another in firms' production functions.

Additionally, in the analysis we wanted to check the influence of the level of novelty on the innovation of the company. We wanted to elaborate whether new to firm innovation could subsequently lead the company to new to market innovation and vice versa. Many studies indicate that companies that have once innovated are more prone to innovation and that's why we propose H3 to elaborate whether different types of product innovations can be considered as being complementary or rivalry innovation.

H3: New to market product innovation and new to firm product innovation complement one another in firms' production functions.

The last hypothesis, H4, aims to elaborate the relationship between organizational (or non-technological) and technological innovation. Many studies show that companies that have undertaken product and process innovation are more likely to engage into organizational innovation and also many studies indicate that companies that have combined both organizational and technological innovation (product and process) achieve higher profit margins (Doran, 2012). That's why we propose the fourth hypothesis to check the complementary relationship among technological and organizational innovation.

H4: Organizational innovation complements product and process innovation in firms' production function.

Additionally, we believe that the impact of the complementary/substitutability relationship is dependent on the development of the economy and vice versa. This assumption appears because, CIS database covers all sectors of the economy and capture information on many different aspects of firm's innovative efforts. The innovations are not based on individual creativity, but instead the firms depend on the relationships among: owners, employees, governments, and sources of finance. Therefore, analysis of these hypothesis is crucial for economic and management studies on understanding the innovation process (Smith, 2005; Mairesse and Mohnen, 2010).

To statistically verify our hypotheses, we employ the methodology developed in Athey and Stern (1998) and subsequently utilized in Mohnen and Roller (2005) and Doran (2012). The methodology is based on super modularity Wald coefficient restriction tests for complementary relationships and sub modularity Wald coefficient restriction tests for investigating the potential substitute relationships. The advantages of using this procedure testing our hypotheses is that it is possible to control all combinations of innovation activity and thus avoiding potential endogeneity problems experienced in other specifications. We refer to Athey and Stern (1998) for more detailed background on the methodology.

3.3. Data

To study whether different forms of innovation are complements or substitutes in Central and Eastern European countries and in Western European countries we exploit the data provided by Eurostat in their Community Innovation Survey (CIS2014). The CIS2014 represents a harmonized survey which aims to collect micro-data on innovation activities conducted between 2012 and 2014 in enterprises from EU member states and a number of European Statistical System (ESS) member countries. Since the dataset provides statistics broken down by countries, type of innovators, economic activities, and size classes, we focus on cross-sectional samples for two group of countries: Central and Eastern Europe comprising of: Bulgaria, Croatia, Hungary, Romania and Slovakia; and Western European countries: Greece, Spain, Norway and Portugal. The set of countries used for the analysis was determined on the basis of the availability of data: only these 9 countries had CIS2014 data for every variable included in the statistical analysis.

Using these data, we measure the output Y_i of the firm as the turnover in euros at the end of 2014, the labor L_i as the number of employees in the firm in 2014, and the capital C_i as the expenditures (in euros) in acquisition of machinery in 2014. A slight drawback of the CIS2014 dataset is that it does not provide exact data on the number of employees in the firms. Instead, the firms are grouped into 6 categories depending on whether they have less than 50, more than 50, between 50 and 249, more than 250 employees, between 250 and 499, and above 500 employees. The missing of the exact values of this variable may represent a slight obstacle to our analysis since we require the exact number of employees to measure the labor input. To circumvent this problem, we approximate the number of employees in a firm by recoding the CIS2014 employee variable as the average value of the category in which they belong. This is a simple and effective approach that has been extensively utilized in the literature. Nevertheless, we emphasize that, while this approach is a neat way to deal with our issue, in some cases it may bias the results.

The data used to approximate the observed factors that affect the total factor productivity are defined in a similar way. In particular, the human capital h_i describes assets like education, training, intelligence, skills, health, and other things employers value such as loyalty and punctuality. Much of these data are intangible, and thus difficult to quantify. The CIS2014 dataset offers an approximation for this variable in terms of the fraction of employees which hold a university degree. The research and development variable is simply defined as the log of the magnitude of the expenditures on innovation activities in 2014 per employee (in euros). The types of innovation are measured exactly as defined in the previous section, with the note that the innovation had to be made between 2012 and 2014.

Finally, CIS2014 provides data for the studied innovation types as indicator variables. The definition of the indicator variables is the same as the definition for the innovation types given in Section 3.2.

Table 1 shows the descriptive statistics of the variables for the two group of countries. It can be observed that in both groups most frequent innovation type is organizational innovation, followed by process innovation and new to the firm innovation, while most rare is new to the market innovation. Moreover, the firms in Western Europe have more often introduced innovations. For example, organizational innovations are done by 29% of firms in Western Europe sample and by 12% of firms in Central and Eastern sample. Also, the firms in Western Europe have, on average, larger turnover per employee, spend more money on machinery and innovative activities, have a larger fraction of employees with a university degree and more employees in general. This allows us to conjecture that there might be significant differences in the relationships between innovation types in the two groups of countries. In the next section, we investigate whether this is indeed true.

Table 1. Descriptive Statistics of CIS 2014

	WE					CEE				
Variable	**mean**	**std. dev.**	**median**	**minimum**	**maximum**	**mean**	**std. dev.**	**median**	**minimum**	**maximum**
Turnover per employee (in euros)	234246.83	1566765.43	79617.79	0.00	164000000.00	98100.79	518111.60	27274.17	0.00	33194853.76
Organizational (1 if the firm introduces an organizational innovation, otherwise 0)	0.29	0.45	0.00	0.00	1.00	0.12	0.32	0.00	0.00	1.00
Process (1 if the firm introduces a new process, otherwise 0)	0.27	0.45	0.00	0.00	1.00	0.10	0.31	0.00	0.00	1.00
New to Firm (1 if the firm introduces a product that is new to firm, otherwise 0)	0.18	0.39	0.00	0.00	1.00	0.08	0.27	0.00	0.00	1.00
New to Market (1 if the firm introduces a product that is new for the market, otherwise 0)	0.15	0.35	0.00	0.00	1.00	0.06	0.23	0.00	0.00	1.00
Expenditure on machinery per employee (in euros)	909.63	29099.19	0.00	0.00	5745480.00	381.31	5497.20	0.00	0.00	432156.98
Number of employees	102.97	138.70	25.00	25.00	700.00	94.47	110.38	25.00	25.00	600.00
Fraction of employees with university degree	0.30	0.31	0.24	0.00	1.00	0.27	0.32	0.09	0.00	1.00
Expenditures on innovation activities per employee (in euros)	3764.06	33601.51	0.00	0.00	5779000.00	745.95	8647.14	0.00	0.00	530971.71
Observations	44907					35319				

3.4.Estimation setup

Several problems may arise if we resort to estimating Eq. (2) solely via the standard Ordinary Least Squares technique. First, there might be endogeneity in the model because the research and development variable is non-zero only for the firms which decided to conduct innovation activities. As such it may be highly correlated with the random error of the model and the output of the firm. To deal with this problem, we follow a Heckman two-step selection procedure akin to the famous Crépon-Duguet-Mairesse (CDM) model for investigating the impact of innovation on the economic output (See Lööf et al. (2017) for an overview on the applications of this model). Through this procedure, in the first set we construct a Tobit regression where the dependent variable is the log of the expenditures on innovation activities per employee. This variable is regressed on the independent variables and three additional indicator variables that should impact the innovation expenditures but not the output of the firm. These are different types of funding that the firm might have received between 2012 and 2014: 1) the local funding, 2) national funding, and 3) EU funding. The estimated expenditures on innovation activities per employee are then used as an independent variable in the estimation of the parameters of Eq. (2). Note that, additional bias may occur because there might be industry specific factors that affect the output but are not captured by our variables. To remove this potential bias, we include in each regression dummy variables for the NACE 2-digit industry classification of the firm.

Second, given that sixteen innovation state variables are included in the model there is the potential that multicollinearity could bias the estimated standard errors of the estimated parameters. In order to assess the degree of multicollinearity, in Appendix 1 we show the correlation matrix between the independent variables of the model. We find that in both samples the correlation between each pair is sufficiently low. This suggests that multicollinearity between the independent variables might not be a problem in the estimation of the production function below.

Lastly, in the tables which summarize the regression results, we display the Newey-West heteroskedasticity consistent standard errors of the parameters as a means to deal with the potential heteroskedasticity in the data.

4. Empirical results

4.1. Productivity function

In Table 2 we present the results from the estimated regressions, using Heckman procedure where productivity measured by log of turnover per employee is regressed on sixteen combinations of innovation and control set of variables. The control variables include expenditure on machinery per employee, number of employees, share of employees with university degree and expenditure on innovation activity per employee, as well as industrial dummies.

The results from the regressions indicate that all types of innovation have statistically significant and positive effect on productivity in the firms operating in both, Central and Eastern European market and Western European market. For CEE firms, introducing all four innovation forms (market & firm & process & organizational) at the same time has the greatest effect on productivity, while the lowest effect has the combination of three innovation forms (firm & process & organizational). In contrary, for WE firms, introducing all four innovation forms (market & firm & process & organizational) at the same time has the lowest effect on productivity, while the highest effect comes from introduction of new product for a firm which is also new for market (simultaneous introduction of market & firm innovations). In general, we highlight that the estimated coefficients in both samples do not show a monotonic increase in productivity with the addition of innovation forms. While this result is in line with the findings of the previous studies that used older CIS surveys (for example, Doran 2012, and Ballot et al. 2015), it is the main reason for assessment of possible complementarity and substitutability in firms' innovation activity that is presented in the sub-section 4.2.

The estimated coefficients of control variables put light on specificities of the countries' groups. Labor inputs shows that while larger firms are found to exhibit higher productivity levels in both groups, higher share of employees with university degree increase productivity only in WE group. This can be explained by the differences in production activity in both groups. The variety of capitalism literature argues that CEE firms engage mostly in assembly and production of relatively complex and durable consumer goods, benefiting from skilled and cheap labor, while the innovation activity is done mostly outside of their borders (Nölke and Vliegenthart, 2009). This also can explain why CEE firms cannot achieve higher productivity with simple increase of expenditures on machinery per employer but need investment in innovation activities. Similarly, the higher coefficient of investment in innovation in CEE than WE imply that the effect of innovation on productivity is higher in the group with lower innovation activity. Also, the positive effects of investment in innovation in both groups are in line with the Romer's endogenous growth theory

Table 2. Estimation of Productivity Function

Variable	**CEE**	**WE**
Innovation interactions		
No Innovation Introduced	4.08* (0.45)	8.13* (0.30)
Organizational Innovation	3.84* (0.44)	8.08* (0.30)
Process Innovation	3.96* (0.45)	8.03* (0.31)
Organizational & Process Innovation	4.06* (0.41)	8.03* (0.30)
Firm Innovation	4.07* (0.45)	8.09* (0.29)
Firm & Organizational Innovation	3.89* (0.44)	7.94* (0.28)
Firm & Process Innovation	3.99* (0.46)	7.87* (0.30)
Firm & Organizational & Process Innovation	3.80* (0.44)	8.01* (0.29)
Market Innovation	4.36* (0.43)	8.18* (0.28)
Market & Organizational Innovation	4.38* (0.41)	8.16* (0.28)
Market & Process Innovation	4.44* (0.42)	8.20* (0.29)
Market & Process & Organizational Innovation	4.45* (0.40)	8.10* (0.28)
Market & Firm Innovation	4.80* (0.40)	8.24* (0.27)
Market & Firm & Organizational Innovation	4.69* (0.39)	8.17* (0.27)
Market & Firm & Process Innovation	5.12* (0.37)	8.01* (0.27)
Market & Firm & Process & Organizational Innovation	5.21* (0.39)	7.89* (0.28)
Independent variables		
Log of expenditure on machinery per employee	-0.39* (0.03)	-0.02 (0.01)
Log of number of employees	0.18* (0.04)	0.20* (0.03)
Share of employees with university degree	0.14 (0.12)	0.36* (0.08)
Expenditures on innovation activities per employee	0.89* (0.07)	0.22* (0.04)

Note: Standard errors in brackets. * denotes significance at 1%. Industry dummies according to NACE classification were included in each regression.

4.2. Differences in innovation relationships

To measure the possible complementarity and substitutability in firms' innovation activity we apply a series of joint Wald tests to estimate the established hypothesis. The results from the Wald tests are displayed in Table 3 and Table 4. The combination of new to firm and process innovation and new to market and process innovation represents hypothesis 1 and 2, respectively. The combination of new to firm and new to market represents hypothesis 3. Finally, the combination of organizational and process innovation, organizational and new to firm innovation and organizational and new to market innovation is given as hypothesis 4.

Critical values for interpreting the results from the Wald tests of super modularity (complementarity) and sub modularity (substitutability) are obtained from Kodde and Palm (1986). The test statistics are assessed using the lower bound value of 5.412 and the upper bound value of 12.483. If the Wald statistics presented in Table 3 and 4 is below the lower bound than the null hypothesis of super modularity or sub modularity cannot be rejected while if the test statistics lies above the upper bound than the null hypothesis is rejected. Values which lie between the upper and lower bound are inconclusive. While the statistics may initially indicate a complementary relationship both test should be taken into account in conjunction with one another to establish whether complementarity or substitutability exists between the analyzed different types of innovations. Strict super modularity is only observed when the null hypothesis of super modularity is not rejected, and the null hypothesis of sub modularity is rejected. For strict sub modularity the situation is reversed. This means that for strict complementarity the super modularity test statistic value must lie below 5.412 while the corresponding sub modularity test statistic value must lie above 12.483. For weak complementarity the super modularity value must lie below 5.412 and the corresponding sub modularity test statistics must lie above 5.412. The reverse applies for strict and weak substitutability.

Table 3. Wald Test Statistics for Super modularity in Innovation Activity

Group	**Firm-Process**	**Market-Process**	**Firm-Market**	**Org-Process**	**Org-Firm**	**Org-Market**
CEE	50.90	24.92	28.94	42.90	45.92	34.81
WE	607.91	595.35	596.78	681.24	633.32	648.41

Note: Critical values at the 1% significance level are 5.412 for lower bound and 12.483 for upper bound based on Kodde and Palm (1986).

Table 4. Wald Test Statistics for Sub modularity in Innovation Activity

Group	**Firm-Process**	**Market-Process**	**Firm-Market**	**Org-Process**	**Org-Firm**	**Org-Market**
CEE	0.78	4.18	6.57	0.21	1.92	2.68
WE	0.00	1.31	1.37	0.00	0.00	0.49

Note: Critical values at the 1% significance level are 5.412 for lower bound and 12.483 for upper bound based on Kodde and Palm (1986).

The results indicate that all values in the test statistics for super modularity for both groups of companies are above the critical level of 5.412. The values of the test statistics for sub modularity in all cases and for both groups of companies are below the critical level of 12.483. These results indicate that in all cases the null hypothesis of super modularity is rejected, and the null hypothesis of sub modularity is not rejected, thus accepted. Actually, we can conclude that instead of complementarity of different innovation activities we have found strict substitutability among them in both Western European market and Central and Eastern European market. In other words, the results indicate that the effect of joint presence of both innovation types (observed in the six innovation pairs) is not larger than the effect of single type of innovation. According to these results, as for the policy strategy of the companies operating on these markets we could not recommend any kind of combination of innovation types. Apparently, better results could be obtained by investing into different types of innovation simultaneously.

Additionally we have done robustness check of the results in appendix A, Tables A3 and A4. We provide the results of supermodularity and submodularity tests estimated separately for each country included in the analysis. We find evidence for existence of synergies between certain types of innovations in three countries: Greece from the Western European group and Slovakia and Croatia from the Central and Eastern European group. For Greece all test statistic values for supermodularity in innovation activities lie below 5.412 but all values for submodularity are below the critical value of 5.412. This means that we cannot conclude even weak complementarity for the companies operating in Greece. The results are inconclusive in regards of the relationship among innovation types. We have also received inconclusive results for the interaction between two innovation pairs for Croatia: firm and market innovation and organizational and market innovation. Only in Slovakia, we have found different results. We have found strong complementarity for organizational and market innovation and weak complementarity relationship between two innovation pairs: new to market and process innovation and new to firm and new to market innovation. For the other innovation pairs the results are inconclusive. These results indicate that for the companies operating in Slovakia possible strategy to improve competitiveness would be to simultaneously introduce new to market innovation (new products or services to the market) and organizational innovation (introduction of new business practices or new methods of organizing the business activities). Unfortunately, in the rest of the countries, in both country groups, the results show strict substitutability among innovation pairs. Apparently the influence of the results from the three above mentioned countries: Croatia, Greece and Slovakia is small and as a group the results indicate strict substitutability among all innovation types.

These results and robustness checks probably indicate the main limitation of our research. In future analysis of the complementary relationship among innovation types we should probably be more focused into analyzing separate innovation system of a certain country and try to explore the possible relations. Apparently, when analyzing innovation systems we should elaborate the specific characteristics of a certain country and national innovation system and try to find the possible reasons for the results or the influence that innovations have on increasing companies' productivity and competitiveness.

5. Conclusion

In this paper we explore the existing interrelationships between innovation activities and productivity performance of firms as well as the complementarities between innovation strategies in Central and Eastern European countries and Western European countries. We considered four different types of innovation activities: organizational innovation, process innovation, new to firm innovation and new to market innovation. We found that all types of innovation have statistically significant and positive impact on the productivity in the companies operating in both, Central and Eastern European market, and Western European market. In relation to the higher level of innovations introduced by companies operating in Western Europe, the coefficients for the companies operating on this market are almost double than the coefficients for the companies operating in Central and Eastern European countries in all sixteen unique innovation variables.

The variables measuring the companies' specific factors indicate slightly different results. The variable measuring the expenditure of machinery per employee (which can be indicated as being capital intensive) shows negative influence over productivity function in both countries settings. And the variables measuring the influence of labor on productivity: number of employees, share of employees with university degree and expenditures on innovation activities per employee are positive and significant in both groups of countries. These results show that bigger influence over productivity has been performed by investing in human resources, especially in employees with university degree and in increased expenditures on innovation activities per employee in both groups of companies.

By applying a series of joint Wald tests, we investigated the established four hypothesis for the possible complementarity and substitutability in firms' innovation activity in both country settings. Unfortunately, the results have shown that among the six possible combinations of innovation activities covered with the four hypothesis there isn't any complementarity relation. The innovation activities appear to be substitutes among themselves and according to this notion the companies should simultaneously invest in all types of innovation activity. As regards to policy recommendations, if we take into account the results that we have obtained we could say that the companies should invest into those innovation activities that have the highest coefficient for productivity increase.

For the companies operating in Central and Eastern Europe the highest coefficient is observed when all four analyzed types of innovations are combined and applied (market, firm, process and organizational innovation). For the companies working at the Western European market the highest coefficient is observed when market and firm innovation are combined, which means technological innovations. Unfortunately we cannot recommend any kind of combination of innovation types as a possible company strategy that through complementary relationship could lead to increased productivity. The companies could obtain better results by investing into different types of innovation simultaneously.

With the robustness checks that we have done separately for the individual countries we have found that for the companies operating in Slovakia there is complementary relationship between new to market and organizational innovation. This means that we could recommend that in Slovakia the companies should combine new to market and organizational innovation. When doing this combination the companies might obtain biggest positive results for increasing their competitiveness and productivity. We have also found weak complementarity among new to market and process innovation and new to firm and new to market innovation in Slovakia.

The results that we have obtained with our research indicate possible shortcomings and limitations. We should elaborate the specific characteristics of a certain country and national innovation system and try to find the possible reasons for the results or the influence that innovations have on increasing companies' productivity and competitiveness. When doing analysis as a group and when the results don't show any complementarity it is very difficult to diagnose the possible reasons and offer solutions. Another limitation is the fact that the dataset is cross-sectional and in order to draw valid conclusions it would be more appropriate to do panel data framework and to analyze the issue across time. Also, another way to obtain more precise results would be to split and analyze the data by sector or size of the firm. But, all these limitations and shortcoming could be good basis for future research in this area.

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Appendix A

Table A1. Correlation matrix for innovation relationships for CEE group

	No Innovation Introduced	Organizational Innovation	Process Innovation	Organizational & Process Innovation	Firm Innovation	Firm & Organizational Innovation	Firm & Process Innovation	Firm & Organizational & Process Innovation	Market Innovation	Market & Organizational Innovation	Market & Process Innovation	Market & Process & Organizational Innovation	Market & Firm Innovation	Market & Firm & Organizational Innovation	Market & Firm & Process Innovation	Market & Firm & Process & Organizational Innovation
No Innovation Introduced	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.03	-0.26
Organizational Innovation	-0.01	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.17
Process Innovation	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	-0.10
Organizational & Process Innovation	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.15
Firm Innovation	-0.01	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.18
Firm & Organizational Innovation	-0.01	-0.01	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.16
Firm & Process Innovation	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	-0.10
Firm & Organizational & Process Innovation	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	-0.02	-0.01	-0.02	-0.03	-0.19
Market Innovation	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	1.00	-0.02	-0.01	-0.02	-0.02	-0.02	-0.03	-0.24
Market & Organizational Innovation	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	1.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.22
Market & Process Innovation	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	0.00	-0.01	-0.01	-0.01	1.00	-0.01	-0.01	-0.01	-0.02	-0.14
Market & Process & Organizational Innovation	-0.02	-0.02	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	1.00	-0.02	-0.03	-0.04	-0.29
Market & Firm Innovation	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	1.00	-0.02	-0.03	-0.24
Market & Firm & Organizational Innovation	-0.03	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	-0.02	1.00	-0.04	-0.32
Market & Firm & Process Innovation	-0.03	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03	-0.03	-0.03	-0.02	-0.04	-0.03	-0.04	1.00	-0.42

Market & Firm & Process & Organizational Innovation	-0.26	-0.17	-0.10	-0.15	-0.18	-0.16	-0.10	-0.19	-0.24	-0.22	-0.14	-0.29	-0.24	-0.32	-0.42	1.00

Table A2. Correlation matrix for innovation relationships for WE group

	No Innovation Introduced	Organizational Innovation	Process Innovation	Organizational & Process Innovation	Firm Innovation	Firm & Organizational Innovation	Firm & Process Innovation	Firm & Organizational & Process Innovation	Market Innovation	Market & Organizational Innovation	Market & Process Innovation	Market & Process & Organizational Innovation	Market & Firm Innovation	Market & Firm & Organizational Innovation	Market & Firm & Process Innovation	Market & Firm & Process & Organizational Innovation
No Innovation Introduced	1.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	-0.04	-0.03	-0.02	-0.04	-0.05	-0.05	-0.07	-0.21
Organizational Innovation	-0.02	1.00	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	-0.03	-0.03	-0.04	-0.13
Process Innovation	-0.02	-0.01	1.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02	-0.03	-0.09
Organizational & Process Innovation	-0.02	-0.01	-0.01	1.00	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.02	-0.03	-0.03	-0.04	-0.12
Firm Innovation	-0.03	-0.02	-0.01	-0.02	1.00	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	-0.04	-0.04	-0.05	-0.18
Firm & Organizational Innovation	-0.03	-0.02	-0.01	-0.01	-0.02	1.00	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	-0.13
Firm & Process Innovation	-0.02	-0.01	-0.01	-0.01	-0.02	-0.01	1.00	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.03	-0.11
Firm & Organizational & Process Innovation	-0.03	-0.02	-0.01	-0.02	-0.02	-0.02	-0.01	1.00	-0.03	-0.02	-0.02	-0.02	-0.03	-0.04	-0.05	-0.15
Market Innovation	-0.04	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	1.00	-0.03	-0.02	-0.04	-0.05	-0.05	-0.07	-0.22
Market & Organizational Innovation	-0.03	-0.02	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03	1.00	-0.02	-0.03	-0.04	-0.04	-0.05	-0.17
Market & Process Innovation	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02	1.00	-0.02	-0.03	-0.03	-0.04	-0.13
Market & Process & Organizational Innovation	-0.04	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.02	-0.04	-0.03	-0.02	1.00	-0.04	-0.05	-0.06	-0.19
Market & Firm Innovation	-0.05	-0.03	-0.02	-0.03	-0.04	-0.03	-0.02	-0.03	-0.05	-0.04	-0.03	-0.04	1.00	-0.06	-0.08	-0.25
Market & Firm & Organizational Innovation	-0.05	-0.03	-0.02	-0.03	-0.04	-0.03	-0.03	-0.04	-0.05	-0.04	-0.03	-0.05	-0.06	1.00	-0.08	-0.27
Market & Firm & Process Innovation	-0.07	-0.04	-0.03	-0.04	-0.05	-0.04	-0.03	-0.05	-0.07	-0.05	-0.04	-0.06	-0.08	-0.08	1.00	-0.35
Market & Firm & Process & Organizational Innovation	-0.21	-0.13	-0.09	-0.12	-0.18	-0.13	-0.11	-0.15	-0.22	-0.17	-0.13	-0.19	-0.25	-0.27	-0.35	1.00

Table A3. Supermodularity tests per country.

Innovation combination	CEE Countries					WE Countries			
	Bulgaria	Croatia	Hungary	Romania	Slovakia	Greece	Norway	Portugal	Spain
Firm-Process	33.48	9.66	90.17	18.38	0.38	0.28	67.97	137.44	274.09
Market-Process	13.42	6.74	87.19	21.77	0.00	0.25	50.98	158.33	263.55
Firm-Market	16.59	3.71	97.24	15.81	0.00	0.21	55.95	120.99	289.06
Org-Process	18.95	20.77	80.65	29.43	1.49	0.35	56.34	122.30	360.96
Org-Firm	20.72	9.02	100.40	14.69	0.01	0.24	59.13	145.91	302.56
Org-Market	19.67	3.87	101.65	30.69	0.00	0.31	60.80	167.50	292.89

Table A4. Submodularity tests per country.

Innovation combination	CEE Countries					WE Countries			
	Bulgaria	Croatia	Hungary	Romania	Slovakia	Greece	Norway	Portugal	Spain
Firm-Process	**0.16**	**1.63**	**0.01**	**0.73**	**4.68**	**0.02**	**0.00**	**0.00**	**0.01**
Market-Process	**0.97**	**1.15**	**2.65**	**0.00**	**12.30**	**0.82**	**0.70**	**5.41**	**0.26**
Firm-Market	**0.31**	**4.87**	**0.39**	**0.56**	**8.80**	**0.16**	**0.68**	**1.80**	**0.19**
Org-Process	**1.13**	**0.00**	**0.00**	**0.00**	**4.13**	**0.34**	**0.09**	**0.58**	**0.00**
Org-Firm	**1.20**	**0.62**	**0.00**	**0.61**	**4.94**	**0.10**	**0.00**	**0.00**	**0.08**
Org-Market	**0.24**	**1.91**	**0.41**	**0.00**	**13.23**	**0.99**	**0.00**	**5.42**	**0.56**

Table A5. Literature review summary

Authors	Main objective of the study	Data sample	Data source	Methodology	Main results
Ester Martinez-Ros and José M. Labeaga 2009	Complementarities between product and process innovations	Spanish manufacturing firms during the period 1990–1999	The Spanish Ministry of Science and Technology,s urvey called ESEE-Encuesta Sobre Estrategias Empresariales	Discrete choice models	Complementary relationship between product and process innovation

Miravete and Pernias 2006	Complementarity among production and innovation strategies	Spanish ceramic firms for 1988 and 1992	DIRNOVA database, database of Spanish firms	Structural discrete choice model	Complementary relationship between product and process innovation
Schmidt and Rammer, 2007	Determinants and effects of non-technological innovations	German firms in the period 2002-2004	German Community Innovation Survey (German CIS 4).	Interaction terms and cluster methodologies	Product innovation is related to organizational innovation
Ballot et al., 2015	Relationships among product, process and organizational innovation	French and UK manufacturing firms, 2002-2004	Community Innovation Survey (CIS4)	Tests for complementarity and substitutability	Complementarities between product and process innovations in French and UK firms and between organizational and product innovations in French firms
Reichstein and Salter (2006)	Relationship between product and process innovation	2885 UK manufacturing firms	CIS 2000 (1998-2000)	Multinomial (polytomous) logistic regression model	Complementarity between product and process innovation
Doran 2012	Complementarities between four forms of innovation	582 Irish firms	Irish CIS 2006	Tests for complementarity and substitutability	Strict complementarity for new to the market product and organizational innovations, and, for new to the firm product and process innovations, and weak complementarity between process and

					organization innovations.
Carboni, O. A., and Russu, P. (2018)	Relationship in process, product, and organizational innovations	12,872 cross-European firms	EFIGE dataset (European firms in the global economy)	Multivariate probit model	Interdependence between the product, process and organizational innovations.