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Abstract

We explore the complementarities between technological and organizational innovations by utilizing cross-sectional data taken from the Community Innovation Survey - CIS2012 for two group of countries: Central and Eastern Europe (CEE - Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Romania, Slovakia and Slovenia) and Western European countries (WE - Germany, Spain, Norway and Portugal). We find that in CEE there is no complementarity between the different types of innovation analyzed. On the other hand, we show that probably in WE there is complementary relationship between organizational and process innovations, but not between organizational and product innovation. Altogether, this indicates that there is a variety in the relationships between the types of innovation in more developed countries (the WE group), but not in less developed countries (CEE group).

Keywords: innovation, complementarity, CDM model, Western Europe, Central and Eastern Europe.

JEL Codes: O31, O33.

1. Introduction

This paper tries to explore the relationship between product, process and organizational innovation and furthermore the effects on performance when combining these innovation activities. The aim of this paper is to determine whether firms by undertaking different forms of innovation simultaneously gain more benefit than firms that undertake the same forms of innovation separately. 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 in by Leiponen (2005), Cassiman and Veugelers (2006), Ballot et al. (2015).

Many of the studies focus on determinants and relationship between types of innovation in developed countries and consequently policy makers from developing countries take over the solutions in shaping their own innovation policies. Therefore, the correlation between the forms of innovation differences in this paper is analyzed across sub-samples from two groups of countries: Western Europe (WE) and Central Eastern Europe (CEE). The data is derived from the Community Innovation Survey -

CIS2012. Most companies in WE were found to be complex internal innovators or complex innovators. However, the Central and Eastern European countries after the period of transition towards market economy, faced challenges in reconstruction of their innovation system. Moreover, the transition shock made significant reductions in the R&D expenditure due to lack of funds. This papers tries to allocate the differences in innovation performance in both institutional settings and give policy recommendation since the East-West innovation gap still exists in Europe (Krammer, 2009).

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 the pructivity level (Porter and Ketels, 2003; Bloom and Van Reenen, 2007).

In CEE, the largest shares of companies were exclusively work management oriented (Sakowski et al., 2018). The behavior of firms in CEE is still based on the same foundations as in the earlier years of transition, such that these firms exhibit many characteristics of price-competitive firms (Stojcic, Hashi and Telhaj, 2013). CEE firms have more formalized organization structure that can take years to change into more dynamic and innovation organization (Sakowski, Vadi and Merikull, 2015). Since the entrance in the EU, cohesion funds increased the innovation opportunities.

As the CEE firms converge with WE firms in terms of firm size, business type, internationalization and other innovation activities, due to the process of conversion it is expected that most of the gaps will be closed.

2. Literature review

The main focus of this paper is to explore the relationship between four types of innovation: 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, 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 labour productivity through introducing organizational changes. Introducing marketing changes appears to be less important and not cost efficient for improving labour 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 the 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 complementarities or substitutability among different types of innovations in the knowledge augmented production function. The nature of the relationship between different types of innovation can go in two directions: technological innovation and non-technological innovation. Technological innovation or complementary relationship between product and process innovation is confirmed in the studies of Martinez-Ros (2000) and Miravete and Pernias (2006). Some authors confirm complementarity relationship between technological and organization innovation such as the studies of Schmidt and Rammer, 2007 and Mol and Birkinshaw, 2009). They confirmed close relationship between new to market innovation and organizational innovation.

However, there is mixed findings regarding the technological or non-technological innovation when analyzing innovation pattern in different countries. Ballot, G. et al., 2015 find that conditional complementarities exist between product and process innovations in French and UK firms and between organizational and product innovations in French firms, but no complementarities between all three forms of innovation. Berulava and Gogokhia, 2018 also reveal that complementarity exists between product and process innovation and alsoin process and non-technological innovations (marketing and organizational innovation) in transition economies, on the basis of BEEPS V dataset and using extended CDM model. 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., & 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 innovation (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 though economies of scale and enhance its market image. That will have positive effect on increasing productivity.

Summarizing the existing empirical findings, we hypothesize that:

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.

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

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

This paper is among the first to investigate simultaneously the complementarities between technological (product and process innovation) and

organizational (process or product and organization) innovations on cross-sectional samples for two group of countries: Central and Eastern Europe and Western European countries. This helps to enrich the understanding of the relations between different forms of innovation and finally, the implications of our finding can be used to help firms to choose the proper strategy in order to improve their firm`s performance. The options can be pure technological innovation strategy or organizational restructuring. Instead of exploring the effect of technological and organization innovation separately (Damanpour 2014; 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 (1971). Therefore the presence of complementarities depends on the national context as well as on firm size and firm capabilities.

3. Data

To study whether different forms of innovation are complements or substitutes in Central and Eastern European countries we exploit the data provided by Eurostat in their Community Innovation Survey (CIS2012). The CIS2012 represents a harmonized survey which aims to collect micro-data on innovation activities conducted between 2010 and 2012 in enterprises from EU member states and a number of ESS member countries. Since the dataset provides statistics broken down by countries, type of innovators, economic activities and size classeswe focus on cross-sectional samples for two group of countries: Central and Eastern Europe (new EU members) comprising of: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Romania, Slovakia and Slovenia; and old European (Union) countries: Germany, Spain, Norway and Portugal.

However, we use micro-data CIS2012 which 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. The missing of the exact values of this variable creates an obstacle to our analysis since some of the other variables have to be scaled down to their “per employee” counterparts in order for adequate comparison between the firms. To circumvent this problem we approximate the number of employees in a firm by recoding the CIS2012 employee variable as the average value of the interval in which the firm was stationed.

Table 1 shows the summary statistics of the innovation and productivity variables. It can be observed that the percentages of firms engaged into different types of innovations are higher for the subset of CEE countries. But if we take into consideration the number of firms observed we can conclude that, on the contrary, the number of WE firms engaged into innovations is greater than the one in CEE countries. In the sample of CEE countries we can see that 42% of the firms were engaged in organizational innovations, 56% in process innovations, 44% in new to firm innovation and 31% in new to market innovation. From the sample of Western European firms, we can observe that 32% of the firms were engaged into organizational innovations, 30% into process innovations, 21% into new to firm innovation and only 16% in new to market innovation.

Table 1. Descriptive Statistics of CIS 2012

Variable	CEE	WE
Turnover per employee	167123.85 (750182.79)	267146.27 (1610088.11)
Innovations:		
Organizational	0.42 (0.49)	0.32 (0.47)
Process	0.56 (0.50)	0.30 (0.46)
New to Firm	0.44 (0.50)	0.21 (0.41)
New to Market	0.31 (0.46)	0.16 (0.37)
Controls:		
Capital per employee (euros)	446764.97 (9143133.25)	1504.01 (34431.96)
Labor	145.90 (155.13)	120.08 (169.14)
Observations	9956	42043

Note: Standard deviations in brackets.

In addition to these four forms of innovation, the size of the firm measured by the number of employees and the capital per worker are also controlled for. It has been shown that these factors are vital to control for in firm's knowledge augmented production functions (Crepon et al. 1998; Roper et al. 2008). The average number of employees is 146 in the sample of CEE firms and 120 in the WE sample of firms. The average capital per employee is significantly higher for the companies in CEE (446,764.97 Euros) but with a big standard deviation of 9,143,133.25 Euros. In the WE sample the average capital per employee is 1,504 Euros with lower standard deviation.

The measure of productivity used in the analysis is the turnover per worker and it indicates that the average level of productivity is significantly higher for the companies operating in Western Europe when compared to the companies operating in Central and Eastern Europe.

4. Empirical methodology

This paper employs the methodology developed in Athey and Stern (1998) and utilized in Mohnen and Roller (2005) and Doran (2012) to estimate the relationship between different types of innovation in the productivity of a firm. The methodology allows for an analysis of whether various combinations of innovation output act as complements or substitutes in firm's production functions. The types of innovation output considered are: new to firm product innovation, new to market product innovation, process innovation and organizational innovation. In order to analyze the effects of various combinations of innovation on firm performance a series of mutually exclusive binary variables for each combination is generated. In total 16 possible states exist for firms. For detailed definition of the other variables please see Doran (2012).

Given that sixteen innovation state variables are included in the model there is the potential that multicollinearity could bias the results of the estimation. In order to assess the

Table 2. OLS Estimation of Production Function

Variable	CEE	WE
Innovation Indicator		
No Innovation Introduced	8.94 (0.09)	9.76 (0.06)
Organizational Innovation	9.28 (0.11)	9.95 (0.06)
Process Innovation	9.34 (0.09)	9.85 (0.06)
Organizational & Process Innovation	9.68 (0.10)	9.93 (0.06)
Firm Innovation	9.08 (0.09)	10.19 (0.06)
Firm & Organizational Innovation	9.49 (0.11)	9.92 (0.07)
Firm & Process Innovation	9.41 (0.10)	9.83 (0.07)
Firm & Organizational & Process Innovation	9.63 (0.10)	9.97 (0.06)
Market Innovation	9.40 (0.11)	10.55 (0.07)
Market & Organizational Innovation	9.58 (0.14)	10.05 (0.08)
Market & Process Innovation	9.58 (0.11)	9.84 (0.07)
Market & Process & Organizational Innovation	9.71 (0.11)	9.98 (0.07)
Market & Firm Innovation	9.57 (0.12)	10.24 (0.07)
Market & Firm & Organizational Innovation	9.37 (0.13)	10.09 (0.08)
Market & Firm & Process Innovation	9.48 (0.11)	10.05 (0.08)
Market & Firm & Process & Organizational Innovation	9.77 (0.10)	10.14 (0.06)
Company Specific Factors		
Log Capital	0.03 (0.00)	0.02 (0.00)
Log Labor	0.22 (0.01)	0.2 (0.01)

Note: Standard errors in brackets. All coefficients are statistically significant at 1%. Industry dummies according to NACE classification were included in each regression.

degree to which multicollinearity may be present a correlation matrix of the innovation state variables is created separately, one for WE sample and one for CEE sample of firms. The tables are given in Appendix 1 and show that the degree of correlation between the variables is sufficiently low in both samples. This implies that multicollinearity among the regressors won't be a problem in the estimation of the production function below (Table 2).

To test for complementarity a test of supermodularity is applied consistent with the one outlined by Athey and Stern (1998). The advantages of using this strict test for supermodularity and submodularity is that it is possible to control all combinations of innovation activity and thus avoiding potential endogeneity problems experienced in other specifications. CIS 2012 allows us with a large dataset which is compatible for usage with this test.

5. Empirical results

In Table 2 we present the results from the estimated regressions. The sixteen unique innovation variables are included, as well as the controls for capital and labor.
The results from the regressions indicate that all types of innovation have statistically significant and positive influence over the productivity in the companies operating in both, the Central and Eastern European market and the Western European market. Productivity is measured as the log of turnover per employee. The coefficients are slightly bigger in the Western European sample compared to the CEE sample of companies. Disparities in productivity may be related to other factors, such as infrastructure, human capital, and levels of research and development, which have a uniform effect on productivity in all sectors. (Ezcurra & Pascual, 2007).

The variables measuring the companies' specific factors also indicate positive and significant influence. Firms with a higher degree of capital per worker are more productive consistent with the existing literature on the knowledge augmented production function. The significant labor coefficients suggest that larger firms are found to exhibit higher levels of turnover per worker which is consistent with increasing returns to scale in production.

To measure the possible complementarity and substitutability in firms' innovation activity we have applied 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. Each combination of innovation activities displayed in Table 3 and 4 relates to the hypotheses developed earlier. 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 supermodularity (complementarity) and submodularity (substitutability) are obtained from Kodde and Palm (1986). It is not possible to utilize the traditional f-distribution to calculate the critical values for these tests.

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 supermodularity or submodularity 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 innovation. Strict supermodularity is only observed when the null hypothesis of supermodularity is not rejected and the null hypothesis of submodularity is rejected. For strict submodularity the situation is reversed. This means that for strict complementarity the supermodularity test statistic value must lie below 5.412 while the corresponding submodularity test statistic value must lie above 12.483. For weak complementarity the supermodularity value must lie below 5.412 and the corresponding submodularity test statistics must lie above 5.412. The reverse applies for strict and weak substitutability.

Table 3. Wald Test Statistics for Supermodularity in Innovation Activity

Group	Firm-Process	Market-Process	Firm-Market	Org-Process	Org-Firm	Org-Market
CEE	2.03	4.29	1.84	0.63	1.54	4.91
WE	17.93	37.39	28.8	2.02	17.83	27.06

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 Submodularity in Innovation Activity

Group	Firm-Process	Market-Process	Firm-Market	Org-Process	Org-Firm	Org-Market
CEE	0.69	0.82	0.28	2.63	0.9	0.07
WE	8.43	0.86	3.25	24.07	3.42	0.59

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).

In order to interpret the results obtained from the Wald test statistics we will present the situations separately, first the observation of the CEE sample of firms, and then the observation of the WE sample of firms.

For the CEE sample of firms, at a first glance, it can be observed that each innovation activity appears to act as a complement to each other form of innovation as all the Wald statistics are below the lower bound value of 5.412. However, when turning to submodularity tests it can be observed that in neither case it is not possible to reject the null hypothesis of submodularity, as all the values are again below the critical value of 5.412. This suggests that the nature of the relationship between all forms of innovation among the companies operating in Central and Eastern Europe is neither strictly supermodular nor submodular. This ambiguous result is not uncommon in relation to testing the presence of supermodularity and submodularity. When considering innovation, it is possible for the nature of the relationship between two forms of innovation to be altered should an additional, third form of innovation be undertaken. Therefore, it is not possible to refer to these forms of innovation undertaken by firm in CEE as strict complements or substitutes as the nature of the relationship may vary.

The situation for the companies operating in Western Europe is rather quite different. There we can observe strict complementarity between organizational and process innovation. The null hypothesis of supermodularity is not rejected as the value

is below the lower bound (2.02 < 5.412) and the null hypothesis of submodularity is rejected as the value lies above the upper bound (24.07 > 12.483). As for the other five situations, we can observe that the values are above the upper bound indicating that the null hypothesis of supermodularity should be rejected. This indicates that possible submodularity exists between the relationships of those types of innovation. In order to confirm strict submodularity, the null hypothesis of submodularity should be accepted, thus not rejected. Observing the results, we can confirm that strict submodularity exists in four situations or combinations of different types of innovation. In other words, the results indicate that new to market innovation and process innovation; new to firm and new to market innovation; organizational innovation and new to firm innovation; and organizational and new to market innovation are substitutable types of innovation for the companies operating on the Western European market. Substitutability cannot be confirmed for the relationship between new to firm innovation and process innovation.

As an overview of all the results we can observe that for the companies operating on the CEE market we cannot confirm any kind of complementarity among the different types of innovation analyzed. This indicates that there is lack of any kind of synergies between these varieties of innovational activities. As for the situation on the Western European market we observe partial support for the Hypothesis 4 as we found complementary relationship among organizational and process innovation, and not for organizational and product innovation (new to market and new to firm innovation). On the contrary, for these companies we observe that in four different situations, i.e., four different pairs of innovational activities are substitutes among themselves.

6. Conclusion

In this paper we explored the existing interrelationships between innovation activities and productivity performance of firms as well as the complementarities between innovation strategies in WE countries and CEE countries. We considered four different types of innovation activities: organizational, process, new to firm and new to market innovation. We found out that all types of innovation have statistically significant and positive impact on the productivity in the companies operating in both, the Central and Eastern European market and the Western European market. The variables measuring the companies' specific factors also indicate positive and significant influence. Firms with a higher degree of capital per worker are more productive consistent with the existing literature on the knowledge augmented production function. The significant labor coefficients suggest that larger firms are found to exhibit higher levels of turnover per worker which is consistent with increasing returns to scale in production.

By applying a series of joint Wald tests, we investigated the established hypothesis for the possible complementarity and substitutability in firms' innovation activity in both country settings. The results for the CEE group of countries showed that for the companies operating on that market probably there is no complementarity between the different types of innovation analyzed. We used this result to hypothesize that there is lack synergies the varieties of innovational activities in the companies operation on the CEE market.

As for the situation of the companies operating on the Western European market, we observed partial support for the stated Hypothesis 4 as we found complementary relationship between organizational and process innovation. Interestingly though, for the companies operating in this market we discovered that four

different pairs of innovational activities are substitutes among themselves. The pairs were: new to market innovation and process innovation; new to firm and new to market innovation; organizational innovation and new to firm innovation; and organizational and new to market. However, substitutability could not be confirmed for the relationship between new to firm innovation and process innovation.

Altogether, this indicates that there is a variety in the relationships between the types of innovation in more developed countries (the WE group), but not in less developed countries (CEE group). In this context, we believe that the investigation for the reasons behind the differences between country types represents a fruitful avenue for future research.

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