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Spatial Analysis of High-Tech Export Performance of the Eastern European Member States of the EU

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Abstract

Some Central and East European countries have integrated into the European Union after 2004 and followed free market economy principles. This paper studies the spatial spillovers effects of high-tech export, Gross Domestic Product per capita, research and development expenditure, number of research and development full time equivalent, and technology accumulation among European Union member Central and East European countries over the period 2007-2020 by using spatial panel estimation models. The main purpose of the paper is to investigate whether high-tech export of European Union member Central and East European countries has a dependency and interaction with each other after EU membership. The estimation results of spatial panel model results reveal that an increment in high-tech exports of adjacent countries increases the high-tech exports of other regional countries. Our results also provide evidence on Gross Domestic Product per capita, and research and development expenditure of European Union member transition economies have positive and significant impacts on high-tech exports of that countries.

Keywords: High-Tech Exports, Spillovers Effects, CEE Countries, Spatial Panel Data

JEL: F10, F14, O33.

1. Introduction

The productivity of countries depends on technological intensity and specialization. Countries could produce new products and increase their productivity levels through technological development and research and development (R&D) investments. In this context, the technology level of countries, especially aftermath of the 20th century, has snappily ranked countries in terms of economic development. Differences in technology among the countries also affect international trade, and competitiveness in the globalizing world economy.

The Lisbon and Europe 2020 strategies of the EU support a knowledge-based economy and sustainable smart growth thanks to innovation policies (Derlukiewicz, 2014; Barrios et al., 2019). However, the innovation

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efficiency of the European Union (EU) regions differs, and it causes income disparities in the union. The Eastern countries need to increase the technological infrastructure to be more competitive in the EU (Foddi & Usai, 2013). The Central and East European (CEE) countries that are the newcomers of the EU have experienced the transition to more liberal market economies. Besides, the EU integration of those countries forces them to be more competitive economies. Under such a circumstance, the EU membership of CEE countries is expected to assist the competitiveness level of countries. Therefore, the main objectives of this study are to examine high-tech export interaction and dependency among EU member CEE countries and reveal the impact of EU membership on knowledge spillover effect for those countries. In addition to this, the study aims to discover the high-tech export determinants of CEE countries.

The basic motivation of this study is to observe the high-tech export spillover effect and find the high-tech export determinants in that region. Hence the research question is whether the high tech export of a CEE country affect the other regional countries after EU membership.

Accordingly, the study employs the spatial panel models as the methodology applied on the EU member CEE countries' high-tech exports, Gross Domestic Product (GDP) per capita, technology accumulation, R&D expenditures, and R&D personnel full time equivalent variables.

The main contributions of that study to empirical literature is in several ways. Firstly, the study examines the high-tech export spillover effect of CEE EU members on each other high-tech export data. Furthermore, the paper emphasizes the impact of income, R&D and technology accumulation on high-tech export of those countries. Also, the study arises out the impact of EU integration over the knowledge spillover of CEE countries. The key findings of our study are that the existence of an interaction among CEE countries for high-tech export and R&D investments and economic development mean more high-tech export for those countries.

The rest of the study is organized as follows. The second part provides a brief literature review. The third section presents the methodology and then introduces spatial econometric methods. The estimation results of the paper are presented in Section 4. Lastly, in the last part, we conclude the paper and propose some policy suggestions.

2. Literature Review

In the literature review, the paper covers selected empirical studies regarding high-tech export of CEE countries. However, initially the theoretical framework of the study has been summarized.

Kuznets (1973) defined the economic growth term as a long-term increasing trend for the capacity of a country to supply diversified economic goods to individuals in its government and mentions that developing technologies are a potential source of economic growth for countries. However, just technological development is not enough for growth. He notes that efficiently and widely using technology accumulates knowledge that will contribute to economic growth by producing innovations. On the other hand, according to Schumpeter (1939), economic growth is seen as a process for development that occurs via external factors created by entrepreneurs. In addition to this, Solow (1956) considers economic growth on physical capital and technological development and asserts that technological development is substantial to achieve sustainable growth in the countries. Moreover, he states that economic growth without technological development slows down and eventually stops due to diminishing returns to capital rule. Eliminating the marginal return of capital with technological development helps to realize long-term growth. Contrary to Solow, Romer (1990) states that product knowledge and the capacity of new creative ideas accelerate the countries' economic growth.

Regarding the growth model based on the technological development, Grossman and Helpman (1990) explain the economic growth through the trade openness of the countries instead of protectionist ones. Also, they note that underdeveloped and developing countries that do not have sufficient R&D stocks could perform their technological developments through technology transfer from developed countries. However, for technology transfer, underdeveloped and developing countries should provide incentives for technology transfer mechanisms and implement various facilitating policies for multinational companies (Grossman & Helpman, 1991: 43). Additionally, Romer (1993) argues that less developed and developing countries would increase their level of technological development and economic growth with the establishment of economic relations with technologically developed countries. Besides, technology-based products create a comparative advantage in international trade, and as a result, the terms of trade of the countries become better along with the effect of technological developments on international trade and economic growth.

The empirical literature admits the high-tech export as a determinant as well as a dependent variable. The composition of export has accepted a component of GDP and directly affects the countries' economic growth (Cuaresma & Worz, 2005; Yoo, 2008; Falk, 2009). Numerous papers analyze the link between innovation, R&D, productivity, and exporting. Also, high-tech export usually captures the technology share in the export and competitiveness of countries. Hence, high-tech export contributes to economic growth. Therefore, countries develop their high-tech export facilities and aim to raise the share in total export to reach a sustainable financial growth path.

On the other hand, studies regarding the determinants of high-tech export are limited. The paper of Zhang (2007) investigates determinants of high-tech export and finds that industrial technology capacity, inward FDI flow, and the infrastructure condition of a country have a positive impact on it. In addition to this, Srholec (2007) suggests that a country's technological capability and size could be associated with high-tech export. Meanwhile, in the literature, the impact of the economic size of a country is blurred. The study of Mathur (1999) demonstrates that the economy of a country is one of the determinants of high-tech trade. In contrast, the paper of Braunerhjelm and Thulin (2008) finds out that the market size of the economy is insignificant for high-tech export but reveals R&D expenditure as a determinant of high-tech export. Moreover, Hatzicronoglou (1997) takes R&D intensity as the indicator of technology and mentions that research is essential for high technology. Lall (2000) implies that high technology consists of high R&D investments and a specialized technical background. Similarly, Tebaldi (2011) observes the positive influence of human capital and discovers that the determinants of high-tech export are economic structure rather than macroeconomic factors such as exchange rate. Besides, countries' R&D activities are evaluated as a catalyst for innovation and productivity in the study of Shefer and Frenkel (2005).

Much of the empirical research accepts the innovation activities favouring export for firm-level (Wakelin, 1998; Caldera, 2010; Becker & Egger, 2013; Love & Roper, 2015). An example related to a firm-level study belongs to Falk and de Lemos (2019), who reveal that R&D intensity and labour productivity are determinants of the firms' export intensity. Another one regarding the firm-level analysis is the paper of Harris and Moffat (2011). The study points out that innovative activities increase the export probability of firms. Nevertheless, Montobbio and Rampa (2005) explore that technological specialization, economic structure, skills, R&D, and FDI impact the export and focus on the technological performance and export at the country level instead of firm-level.

Falk (2009) examined the relationship between high technology exports and economic growth by taking into account R&D intensities and the ratio of business expenditures on R&D to GDP in OECD countries. Moreover, the paper of Ackrill and Cetin (2019) analyses the relationship between R&D spending, patents, and high-tech export and adds that the lack of country-level research regarding these relationships is criticized. Therefore, our paper contributes to the literature regarding country-level high-tech export determinants instead of firm-level to cover the gap in the literature. In addition to this, our paper focuses on the high-tech export and its determinants by using spatial econometric modelling. The variables included in this model as the determinants of high technology exports were derived from the models discussed in different papers in the literature (Gani, 2009; Alemu, 2012; Meo and Usmani, 2014; Sandu and Ciocanel, 2014; Śledziewska and Akhvlediani, 2017; Durmaz and Yıldız, 2020; Drapkin, et al., 2021).

In the literature the growth of CEE countries has been studied and the economic transition of those countries affected the growth rates of countries (Neycheva, 2010; Tamilina & Tamilina, 2017; Cieślik & Goczek, 2018; Gradzewicz et al., 2018; Papava, 2018). Regarding the high-tech export, Matyushenko et al. (2020) assess the reasons of low-level Ukraine high-tech foreign trade and demonstrate that outdate production and a low level of R&D costs cause to Ukraine low high-tech trade capacity. Drapkin et al. (2021) examine 73 groups of products that belong to 27 CEE and Commonwealth of Independent States (CIS). The study reveals that human capital quality, unemployment, tax, wage level, resource prices, and openness rate of countries stimulate high-tech export. Accordingly, we examine the high-tech export of 11 EU member CEE countries and determinants – R&D expenditure share in GDP, technology accumulation, GDP per capita, and the number of R&D personnel full time equivalent – by using spatial econometric models. Such a regional study is the value addition to literature. Besides, another contribution of the paper to the literature is presenting the EU member CEE countries high-tech export dependency and interaction with each other after EU membership.

3. Methodology

The shock on high-tech exports and technological development in a country can also affect technology in other neighboring countries in the region. The relationship between these neighboring countries' high-tech exports reveals that the spatial impact is among the determinants of regional high-tech exports. In this direction, Rey and Montouri (1999) state that regional economic development cannot be considered independent of geographical location considering the spatial effects in their analysis. Moreover, factors such as technology transfer that influence the countries' economic growth and technological accumulation are affected by geographical location. Correspondingly, Anselin (1988) states that the studies examining the regions regarding their economic levels will reach misleading results if they ignore the spatial effects. In this direction, both the regional spillover effects of high technology exports and the determinants of high technology exports in 11 EU member CEE countries are tested via creating a model in line with the literature.

Traditional econometric methods accept the assumptions that the observations are independent of each other and the variance is constant and does not consider spatial effects. Disregarding spatial effects in the regional analysis may cause the model to give misleading results. That is the reason why we use spatial econometric methods in the paper.

Anselin (1988) defines spatial econometrics as the inclusion of geographic differences in the model and states spatial dependence and spatial heterogeneity in spatial econometrics. Spatial dependence is the relationship between random variables measured in a region and the values of random variables in another area. On the other hand, spatial heterogeneity indicates that the parameters in the model and functional structure change according to the region and are not homogeneous for the data set (Anselin, 1988; Lesage, 1999).

After determining the presence of spatial effect in the model, the spatial effect is analyzed by adding the spatial lagged value of the dependent variable to the model as an independent variable (spatial lag model) (1) or error term (spatial error model) (2,3). If the spatial effect is both the dependent variable and error term, the spatial Durbin model is preferred in the analysis (4,5).

$$y = pWy + X\beta + \varepsilon \quad (1)$$

Here ρ is the spatial autoregressive parameter for the spatial lag of the dependent variable, W is the spatial weight matrix, and X is the independent variables vector. Wy shows the average spatial weight of the dependent variable y in neighboring regions.

$$y = X\beta + \varepsilon \quad (2)$$

$$\varepsilon = \lambda W\varepsilon + u \quad (3)$$

Here $\varepsilon \sim (0, \sigma 2I)$ and λ are between -1 and 1. λ is the spatial autoregressive coefficient for error lag. It is assumed that "u" and "ε" are unrelated and "u" is constant variance.

$$y = pWy + X\beta + \lambda WX\beta + u \quad (4)$$

$$u \sim N(0, \sigma^2 I) \quad (5)$$

If the spatial effect is both in the dependent variable of the model and in error terms, the Spatial Durbin Model is more appropriate to analyze spatial results. The Spatial Durbin model is defined as in Equation 10. Accordingly, the proper spatial model will be preferred, and spatial panel data analysis will be performed.

4. Empirical Results

The EU has dominated the ex-Soviet countries in Europe after the collapse of the Soviets, and in the 21st century, the countries have become EU member states. The paper utilizes indicators that explain the high-tech export of 11 EU CEE countries between 2007 and 2020. The main purpose of this study is to reveal whether the spatial spillover effect exists for EU member CEE countries by taking high-tech export data. Moreover, the study intends to demonstrate the determinants of the high-tech export variable of those countries. All variables, definitions and data sources of our dataset are described in Table 1.

High-tech exports are an important tool for the economic development for the developing Eastern European countries after the disintegration of the Soviet Union (Srholec, 2007; Falk, 2009; Gani, 2009; Tebaldi, 2011; Bao et al., 2012; Sara et al., 2012; Sandu and Ciocanel, 2014; Kabaklarli et al., 2017; Śledziewska and Akhvlediani, 2017). In this direction, the variable of high technology exports, which is frequently used in the literature, is included as a dependent variable in the model to test the diffusion of technological developments in Eastern European countries. The per capita income variable is an important indicator that is widely referenced in the literature to represent economic development and is used to explain high technology exports (Kabaklarli et al., 2017; Śledziewska and Akhvlediani, 2017). R&D expenditures are important investments for the technological developments (Srholec, 2007; Falk, 2009; Alemu, 2012; Meo and Usmani, 2014; Sandu and Ciocanel, 2014; Śledziewska and Akhvlediani, 2017; Drapkin et al., 2021). Therefore, it is included in the model as an important indicator for the creation of products subject to high technology exports. R&D personnel represent the skilled labour that has an important role in the development of new technologies (Alemu, 2012; Meo and Usmani, 2014; Sandu and Ciocanel, 2014). In this context, it is included in the model as an important variable for the creation and export of high-tech products. Technological accumulation is an important variable that represents patents that provide protection rights for developed technologies and provides a comparative advantage in high technology exports (Montobbio and Rampa, 2005; Seyoum, 2005; Kabaklarli et al., 2017; Drapkin et al., 2021). In this direction, it is included in the model as an important research variable that explains high technology exports.

The growth rate of the world that follows a linearly increasing trend has reached the highest level in the 21st century. Table 2 demonstrates the GDP per capita and growth rate for the last 2000 years.

In each consecutive period, the growth rate of the world accelerates. In this direction, the GDP per capita in the 2000s close to eightfold of the income in 1900. The 21st century also is the integration years of former socialist European countries to the EU. The summary of the dataset of 11 CEE EU member countries in the period between 2007 and 2020 are given in Table 3 as follows:

Table 1. Variables, Definitions and Data Sources

Variable	Definition	Data Source
High-Tech Export	Natural logarithm of high technology product export of countries in million US $	World Bank
GDP per Capita	Natural logarithm of gross domestic per capita	World Bank
R&D Expenditure	Share of R&D expenditure in gross domestic product	World Bank
R&D Personnel	Natural logarithm of R&D personnel full time equivalent	World Bank
Technology Accumulation	Ratio of patent grants to patent applications	World Intellectual Property Organization

Table 2. World Growth Rates and GDP Per Capita (in 1990 $)

Year	Growth Rate	GDP Per Capita
1	-	590
1000	-0.03	420
1500	0.12	780
1820	0.15	1.240
1900	1.24	3.350
2006	1.94	26.200

Source: Jones, (2016: 6).

Table 3. Descriptive Statistics of Countries between 2007 and 2020by Variables

Country	Variable	Mean	Std. Dev.	Min.	Max.
Bulgaria	High-Tech Export (billion $)	1.28	0.51	0.64	2.17
	GDP per Capita	7876.6	1199.9	5885.1	10079.2
	R&D Exp. Share	0.67	0.16	0.43	0.95
	R&D Personnel	1873.9	365.6	1478.6	2419.9
	Technology Accumulation	0.64	0.35	0.12	1.1
Croatia	High-Tech Export (billion $)	1.07	0.29	0.77	1.59
	GDP per Capita	14121.7	1140.2	11933.3	16416.5
	R&D Exp. Share	0.86	0.14	0.73	1.24
	R&D Personnel	1699.2	256.8	1404.9	2219.8
	Technology Accumulation	0.34	0.213	0.07	0.73
The Czech Republic	High-Tech Export (billion $)	26.5	7.01	17.2	39.5
	GDP per Capita	20708.1	1913.6	17829.7	23660.1
	R&D Exp. Share	1.67	0.28	1.23	1.99
	R&D Personnel	3321.7	486.9	2691.5	4127.9
	Technology Accumulation	0.88	0.31	0.56	1.49
Estonia	High-Tech Export (billion $)	1.8	0.64	0.62	2.61
	GDP per Capita	18870.24	2862.4	14663	23397.8
	R&D Exp. Share	1.55	0.34	1.05	2.3
	R&D Personnel	3348.5	314	2744.9	3846.1
	Technology Accumulation	1.42	1.22	0.15	4.64
Hungary	High-Tech Export (billion $)	18.9	2.35	15.1	23.4
	GDP per Capita	14354.7	1375.6	12720.7	16735.6
	R&D Exp. Share	1.26	0.19	0.95	1.6
	R&D Personnel	2725.6	817.6	1734.9	4357.9
	Technology Accumulation	0.57	0.43	0.09	1.9

Country	Variable	Mean	Std. Dev.	Min.	Max.
Latvia	High-Tech Export (billion $)	1.11	0.53	0.38	1.95
	GDP per Capita	14969.9	2037.7	11420.9	17926.8
	R&D Exp. Share	0.6	0.08	0.43	0.71
	R&D Personnel	1848.2	134.4	1596.5	2158.8
	Technology Accumulation	0.81	0.23	0.46	1.31
Lithuania	High-Tech Export (billion $)	1.92	0.58	0.96	2.81
	GDP per Capita	15515.4	2724.4	11820.7	20232.3
	R&D Exp. Share	0.91	0.1	0.78	1.15
	R&D Personnel	2937.5	340.8	2598	3728.4
	Technology Accumulation	0.83	0.14	0.67	1.12
Poland	High-Tech Export (billion $)	14.6	6.45	4.26	24.5
	GDP per Capita	13583.4	1435.5	11254.5	15742.4
	R&D Exp. Share	0.92	0.25	0.56	1.39
	R&D Personnel	2210.4	656.7	1593.2	3288.1
	Technology Accumulation	0.81	0.27	0.53	1.29
Romania	High-Tech Export (billion $)	4.69	1.65	1.42	7.01
	GDP per Capita	10023.9	1669.5	8214	12956.5
	R&D Exp. Share	0.47	0.04	0.38	0.55
	R&D Personnel	903.1	41.9	790.6	966.2
	Technology Accumulation	0.42	0.15	0.28	0.77
Slovakia	High-Tech Export (billion $)	6.58	2.21	2.92	9.09
	GDP per Capita	17812.5	1188.6	16106	19389.9
	R&D Exp. Share	0.75	0.2	0.44	1.16
	R&D Personnel	2735.1	260.7	2288.3	3164.3
	Technology Accumulation	0.93	0.72	0.32	2.33
Slovenia	High-Tech Export (billion $)	2.02	0.57	1.39	3.41
	GDP per Capita	24206.4	1806.1	20890.1	27595.6
	R&D Exp. Share	2.07	0.33	1.42	2.56
	R&D Personnel	4143.9	566.1	3106.1	5054.7
	Technology Accumulation	0.71	0.09	0.54	0.87

The highest averagely high-tech export belongs to the Czech Republic whereas Croatia has the lowest. Also, the standard deviation of the Czech Republic is more than the other countries. This situation refers to the gradual improvement of the Czech Republic in terms of high-tech goods export.

The GDP per capita average of 11 countries is over 15,000 US $ in the 2007-2020 period. However, Bulgaria and Romania are still the poorest countries of that group and the EU. The GDP per capita difference between Poland (the closest country to Romania) and Romania is almost 35%, but the gap decreased to 18% in 2020. The share of R&D expenditure in the GDP among countries is changeable. The shares of Slovenia, the Czech Republic, Estonia, and Hungary have the highest rates that are at least 1%. However, Romania, Latvia, and Bulgaria have the lowest rates which are below 0.7%.

The number of R&D personnel full time equivalent in Slovenia is 25% higher than the second and third countries – Estonia and the Czech Republic. Lastly, the descriptive statistics of technology accumulation demonstrate that Croatia has the lowest scores in the group.

Autocorrelation tests are applied before building a spatial model in order to determine the specification of model. Moran I Test, Geary C Test (1954), and Getis-Ord G Test was applied to inspect spatial autocorrelations among the countries.

Table 4. Testing for Spatial Autocorrelations

Tests	Statistics	Probability
Moran I	4.347	0.000
Geary GC	0.708	0.000
Getis-Ords GO	0.334	0.000

The results of spatial autocorrelation tests in Table 4 reject the null hypothesis that refers to no spatial autocorrelation. In addition to this, the results show that there are positive spatial correlations and clustering between countries. As listed in Table 5, the Moran I test (ρ), LMρλ test, the classical LM tests, and robust LM tests are performed to analyze spatial dependence.

Table 5. Diagnostic Test Results

Tests	Statistics	Probability
Moran I (ρ)	4.334	0.000
$LM_ρ$ (Spatial Error)	15.916	0.000
Robust $LM_ρ$ (Spatial Error)	27.579	0.000
$LM_λ$ (Spatial Lag)	0.001	0.994
Robust $LM_λ$ (Spatial Lag)	0.001	0.977
$LM_{ρλ}$ (Spatial Lag + Error)	27.579	0.000

The classical LM test results show that the null hypothesis of no spatially lagged dependent variable is not rejected. In contrast, the null hypothesis of no spatially auto-correlated error term is strongly rejected at a 1% significance level. Referring to the robust LM tests, the null hypothesis of no spatially auto-correlated error term is again rejected at a 1% level. The null hypothesis of no spatially lagged dependent variable is not rejected, like the classical LM tests. The results in Table 5 indicate the existence of spatial correlation among the data. Therefore, spatial panel data models are appropriate for traditional panel data models, which do not consider spatial effects in the model.

Table 6 reveals the estimation results of the fixed panel model, spatial error model, and spatial lag model. A Hausman test is performed to determine which one is better between random and fixed effects in Table 6. According to the test results, random effects at 5% significance level are rejected (11.692, $P < 0.05$), and fixed effects models in Table 6 provide more appropriate estimations. The results of LM tests and the Hausman test, the SEM model with spatial fixed effects (SEM FE model) is chosen as the best model estimation.

According to the SEM FE model results, the positive estimated coefficient (0.114) indicates that high-tech exports in neighboring

Table 6. Spatial Model Results

Independent Variables	Dependent Variable: High-Tech Exports		
	Fixed Panel Model	Spatial Error Model	Spatial Lag Model
Technology Accumulation	-0.074	-0.539	-0.001
R&D Expenditure	0.887***	0.876***	0.146***
R&D Personnel	-0.085	-0.165	-0.116
GDP_{pc}	1.498***	1.514***	0.382***
Constant	4.276***	0.061***	0.792**
ρ	-	0.114***	-
λ	-	-	0.468***
Goodness of Fit Tests			
R^2	0.59	0.58	0.97
F Test	297.47 (0.000)	-	-
Wald Test	-	155.93 (0.000)	257.73 (0.000)
Observation	154	154	154
Hausman Test	11.692	**Probability**	0.037

countries positively affect regional high-tech exports. It implies that high-tech exports among countries have spatial spillover effects, meaning that a 1% increase in high-tech exports of adjacent countries will lead to a 0.12% increase in high-tech exports of regional countries. These findings suggest that a change in high-tech exports in each country has a positive spatial spillover effect on high-tech exports in adjacent countries. At the same time, changes in the high-tech exports in neighboring countries also create a positive spatial spillover effect on the high-tech exports in the CEE countries.

4. Conclusion and Discussion

This paper examined the high-tech exports model of EU member CEE countries using the spatial panel data approach to avoid the estimation deviation between 2007 and 2020.

Findings obtained from empirical analyses demonstrate that R&D expenditures and GDP per capita have significant effects on high-tech exports. The results conform with the studies in the literature – Mathur (1999), Cuaresma and Worz (2005), Srholec (2007), Yoo (2008), and Falk (2009) – about the expected relationship between high-tech exports and GDP per capita.

Based on the results of this study, R&D investments and economic development have a positive impact on the high-tech export of the countries. The decision makers of countries may give priority to increasing the share of R&D investments and probably follow economic growth policies for more high-tech export. Also, the sustainable growth policies of those transition countries provide an opportunity to improve the high-tech export volume. The development of one economy in the region triggers the growth of other economies. The collectivity among EU member transition CEE economies also reflects the effectiveness of EU policies and the integration process in the area. Lastly, in further studies, the effects of foreign direct investments and learning-by-doing facilities on high-tech exports in the EU member CEE economies via empirical analyses might contribute to the results of this study.

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