A SPATIAL EVIDENCE ON THE DETERMINANTS OF HIGH-TECH EXPORTS IN THE EUROPE[1,2]

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ABSTRACT

The aim of this study is to analyze the determinants of high-tech exports in the 40 European countries sample from 2011-2021, while considering spatial spillover. To achieve this, a spatial panel data model was employed. The results indicate a positive impact of per capita GDP, per capita patent applications, and trade openness on high-tech exports. However, there is no significant impact of R&D expenditures, foreign direct investment, and economic freedom on high-tech exports. The results showed a differentiation when considering spatial effects. The analysis model revealed the presence of both spatial lag and spatial error. Additionally, the results suggest that high-tech exports from surrounding countries have a positive impact on the high-tech exports of the country. Based on these findings, it is recommended that policymakers work towards eliminating trade barriers between countries, ameliorating income and promoting the commercialization of knowledge.

Keywords: *High-tech export, spatial spillover, European countries*
JEL Code: *C21, C23, O32*

Scope: *Economics*
Type: *Research*

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AVRUPA'DA YÜKSEK TEKNOLOJİ İHRACATININ BELİRLEYİCİLERİ ÜZERİNE MEKÂNSAL BİR KANIT

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ÖZ | Bu çalışmanın amacı, 2011-2021 yılları arasında 40 Avrupa ülkesi örneklemi üzerinden yüksek teknoloji ihracatının belirleyicilerini mekânsal yayılmayı da dikkate alarak analiz etmektir. Bunu başarmak için mekânsal bir panel veri modeli kullanılmıştır. Sonuçlar, kişi başına düşen GSYH, kişi başına düşen patent başvuru sayısı ve ticari açıklığın yüksek teknoloji ihracatı üzerinde pozitif bir etkisi olduğunu göstermektedir. Ancak, Ar-Ge harcamaları, doğrudan yabancı yatırım ve ekonomik özgürlüğün yüksek teknoloji ihracatı üzerinde anlamlı bir etkisi yoktur. Sonuçlar, mekânsal etkiler dikkate alındığında bir farklılaşma göstermektedir. Analiz modeli hem mekânsal gecikmenin hem de mekânsal hatanın varlığını ortaya koymuştur. Ayrıca sonuçlar, çevre ülkelerden yapılan yüksek teknoloji ihracatının ülkenin yüksek teknoloji ihracatı üzerinde olumlu bir etkisi olduğunu göstermektedir. Bu bulgular doğrultusunda, politika yapıcılara ülkeler arasındaki ticaret engelleri kaldırmaya, bilginin ticarileştirilmesi ve gelir düzeyini iyileştirmeye yönelik politikalar üretilmesi önerilmektedir.

Anahtar Kelimeler: *Yüksek teknoloji ihracatı, mekansal yayılma, Avrupa ülkeleri*
JEL Kodları: *C21, C23, O32*

Alan: *İktisat*
Türü: *Araştırma*

1. INTRODUCTION

In the past, disparities in savings and investment opportunities were blamed for the development divide between nations. Today, though, this disparity has grown more intricate, impacting both production and foreign trade. Countries that are unable to engage in the global economy with innovative goods, services, or approaches do not receive a large enough portion of commerce internationally. This implies that the disparities will continue to exist or even increase (Biçen, 2020). In a world where countries are looking for appropriate solutions to widen or close the development gap, the issue of high-tech production is becoming extremely important (Sandu & Ciocanel, 2014). High-tech products have been among the most dynamic parts of international trade over the last 20 years. Rising the portion of high-tech products and improving productivity are the primary goals of today's fast-growing economies to compete with new and high-tech segments of industries (Sara, Jackson & Upchurch, 2012). Srholec (2007) points out that the high-tech products are the most rapidly growing components of the international trade. The export of high-tech products are crucial financial elements for countries that have adopted an export-led growth strategy. By improving their production technologies, countries and firms can increase their export revenues and exports. Thus, exports of high-tech products might provide the necessary basis for sustainable economic growth (Erdinç & Aydınbaş, 2020). In addition to being crucial for economic growth, the export of high-tech products is one method that countries transition into the modern society (Özsoy, Şehvez Ergüzel, Ersoy & Saygılı, 2022). Hidalgo (2015) states that constructing a modern society is contingent upon the effective utilization of knowledge. He suggests that the modernity degree of a society can be measured by its capacity to employ collective and shared knowledge. According to Zeufack (2002), the transition from a traditional to a modern economy is marked by changes in the structure of basic export products and a move towards producing advanced technology and complex products. Tebaldi (2011) also argues that trade in high-tech products can reveal a country's total competitiveness and place in the global technology market. In addition, it helps to capturing the comparative advantages occurred by innovations and high technology between countries.

Success in high-tech exports (HTE) is viewed as a gauge of the competitiveness of the country’s industries. Sectors with high-tech products grow more rapidly than other sectors. This is due to high income elasticity of demand, product innovation and productivity growth. Moreover, the projections of the new economic geography models suggest that high-tech production is subject to increasing economies of scale. If high-tech products are to remain competitive, it will be simpler for the country to maintain export growth (Mani, 2004;

Braunerjhelm & Thulin, 2008). Recognising that achieving a competitive position in the foreign trade market and sustainable economic growth will be more likely through export of high value-added products, policy makers have focused on raising the technological level of the country's export products (Kalkan & Pala, 2022).

The determinants of HTE have been extensively researched by scholars in the literature to design and implement the right policies. However, there is still a lack of studies in the literature on the determinants of HTE, by considering spatial spillover. Spatial effects should be taken into account when analysing the determinants of high technology, especially in Europe, which has recently lost strength in HTE not on a country-by-country basis but on a continent-wide basis. According to the World Bank (2023), while the total HTE of the countries of the European continent accounted for 36 per cent of the world's total HTE in 2011, this share will fall to 26 per cent in 2021. The main motivation of the research is to investigate the existence of spatial spillovers in this decline in HTE. Based on this motivation, the research aims to analyse the determinants of HTE in the sample of 40 European bordering countries by using spatial panel data techniques.

In the literature, the determinants of HTE have been analysed in the European Union (EU) sample or in the sample of selected European countries. Sandu and Ciocanel (2014), Akay (2021) analyses the determinants of HTE in the EU sample, while Gökmen and Turen (2013), Şahbaz, Yanar & Adıgüzel (2014). Bayar, Remeikene & Gaspareniene (2020) analyse the determinants of HTE in the sample of selected European countries. To our knowledge, no study has been found in the literature that analyse the determinants of HTE in a sample covering all countries of the European continent. In this regard, the contributions of the article are mainly in the following two aspects. Firstly, this study analyses the determinants of HTE in a sample of bordering European countries with heterogeneous income levels, as opposed to a sample of selected European countries with a homogeneous income distribution. Secondly, spatial panel data analysis is employed to determine the factors affecting HTE, taking into account neighbourhood and geographical proximity effects.

The remainder of this paper is organized as follows. The next section introduces the determinants of high-tech exports. The Section 3 provides information on the development of HTE in Europe and their distribution across European countries. Section 4 presents the literature review. Section 5 shows the data and methodology. Section 6 demonstrates empirical results. The final section concludes the paper.

2. THEORETICAL FRAMEWORK

Several taxonomies have been proposed over the years to classify exporting industries based on technology intensity, scientific capabilities, sources of competitive advantage, or the overall nature of the innovation process (Srholec, 2007). According to OECD (2011), exporting industries can be classified into four categories based on the level of technology involved: low-technology goods and services, lower-intermediate technology goods and services, upper-intermediate technology goods and services, high-technology goods and services. The high-tech industries encompass aerospace, computer, and pharmaceutical industries. Meanwhile, motor vehicles, electrical equipment, and most chemical industries belong to the medium-high-tech group. Lower-middle industries include rubber-containing plastics, basic metals, and shipbuilding. Lastly, low-tech industries comprise processed food, textiles, clothing, and footwear (Buzdağlı, Uzun & Emsen, 2019). This classification is based on the proportion of research and development expenditures (RDE) and their intensity in the exported goods and services (Biçen, 2020). One technological classification used internationally is that the United Nations Industrial Development Organization (UNIDO). UNIDO (2022) classifies technology intensity based on RDE in the production of manufactured goods. This classification is slightly different from the OECD taxonomy as it consists of three groups. In this taxonomy, high and medium-high technology industries are included in a single group, while medium and low technology industries are grouped separately. UNIDO classification is divided into three categories, unlike the OECD, for two reasons. Firstly, the OECD classification is mainly applicable to highly developed countries, and therefore some manufacturing sectors, such as aerospace machinery, are not common in developing countries. Secondly, compiling data for the three groups is easier than for the existing data, with a few exceptions (Fonkam, 2023).

Both taxonomies consider the intensity of RDE when determining the technological level of exported products. Products with high levels of RDE are considered HTE products. RDE have a two-fold impact on HTE. First, they increase a country's capacity to produce new technology and develop new products. Second, they accelerate the diffusion of technology across countries and/or industries. In countries with high RDE, the process of imitating technology produced in other countries becomes easier, and the technology gap is closed more rapidly (Şahbaz et al., 2014). RDE are inputs in the production of high-tech goods, either directly or through skilled labour (Braunerjhelm & Thulin, 2008). In addition to RDE, patents are regarded as one of the determinants of HTE. Patents are employed to preserve new products and production methods of firms which produce high-tech goods. By applying for patents, innovative companies not only protect their new products from being copied by their competitors, but also surround their own freedom of production with a protective wall (Akyol & Demez, 2020).

Both RDE and patents support HTE through technology accumulation. In addition to these, there are other factors that promote exports of high-tech products through technology accumulation. One such factor is foreign direct investment (FDI). FDI has various impacts on the economy of host countries. FDI not only affects the national production, employment, and balance of payments, but also contributes to the dissemination of new and advanced technologies. FDI can help in achieving competitiveness in HTE products that require advanced learning and skill requirements. This is achieved through the role of multinational companies (Seyoum, 2005).

Multinational companies transfer knowledge and technology from host countries through spillover effects. This encourages the occurrence of new competitive advantages in technology-intensive sectors. FDI flows provide the capital needed to produce technology-intensive goods and upsurge export earnings from these goods in a low-cost environment (Fonkam, 2023). However, the impact of FDI flows on HTE varies depending on the kind of FDI, the quality of human capital, and the level of economic and technological development of countries (Bayar et al., 2020). Yokota and Tomohara (2010) detect a relationship between technology transfer through FDI and the skilled labour capital of host countries. To fully absorb technology spillovers through FDI, there must be a sufficient stock of human capital that corresponds to a threshold value.

Economic freedom is also important for technology transfer through FDI. Investors aim to assure the sustainability of their funds and investments. Therefore, economic freedom is recognised as one of the determinants of whether an economy is deemed as conducive for domestic or international investment. Economic freedom is a significant factor in determining both FDI flows and HTE through technology accumulation. Progress in economic freedom favours exports of high-tech goods by facilitating savings in the technology market and strengthening innovation cooperation between different actors (Gökmen &Turen, 2013). The supply of intermediate goods through imports is also the other way of outsourcing technology accumulation, as is FDI. Producers can use the highest quality intermediate goods through imports in the absence of domestic production (Gunes, Gurel, Karadam & Akın, 2020). In addition to the supply of intermediate goods, trade openness strengthens the export of high-tech products in multiple ways. Firstly, trade facilitates communication channels that ease the diffusion of know-how. In this manner, countries that are not leaders in the development of new technologies benefit from knowledge flows through trade. Secondly, global competition fosters the creation of new products and entrepreneurship. Thirdly, the consumer market grows because of internationalization. Fourth, there are benefits to specialization from international commerce. Ultimately, companies that have access to global markets grow to a level where they can amortize important investments like RDE (Fonkam, 2023). These effects suggest that trade openness is a crucial determinant of HTE. In addition to these determinants, Moraes & Luna (2018), Saraç & Yağlıkara (2022), Fonkam (2023) claim that income is one of the determinants of HTE.

3. DEVELOPMENT AND DISTRIBUTION OF HIGH-TECH EXPORTS IN EUROPE

The competitiveness model of developed countries is based on the production of high-tech products and services, and their inclusion in world markets. This model emphasises the importance of high-tech industries in the global market (Gerasymchuk & Sakalosh, 2007). In recent years, innovation, trade in technology-intensive products, and the resulting economic performance has highlighted the significance production and export processes in the high technology field (Tebaldi, 2014). Therefore, in terms of overall competitiveness in the global economy, a country or region's competitiveness in the field of HTE is crucial (Kılıç, Bayar & Özekicioğlu, 2014). The ability of developing countries to catch up with developed countries by becoming more competitive, and the ability of developed countries to remain competitive, is based on the exporting high-tech products. The ease with which technology can be imitated, thanks to the rapid spread of information, has made it easier for developing countries to produce high-tech products and gain a place in the global market for HTE. As a result of this situation, Europe, the cradle of the industrial revolution, where developed countries have led other countries in economic performance for the past two centuries, have been losing its competitiveness in the global marketplace. The South Asian region's surge in HTE, particularly in the last decade, has undermined Europe's standing in the global HTE market. Figure 1 illustrates the development of HTE in Europe over the last decade.

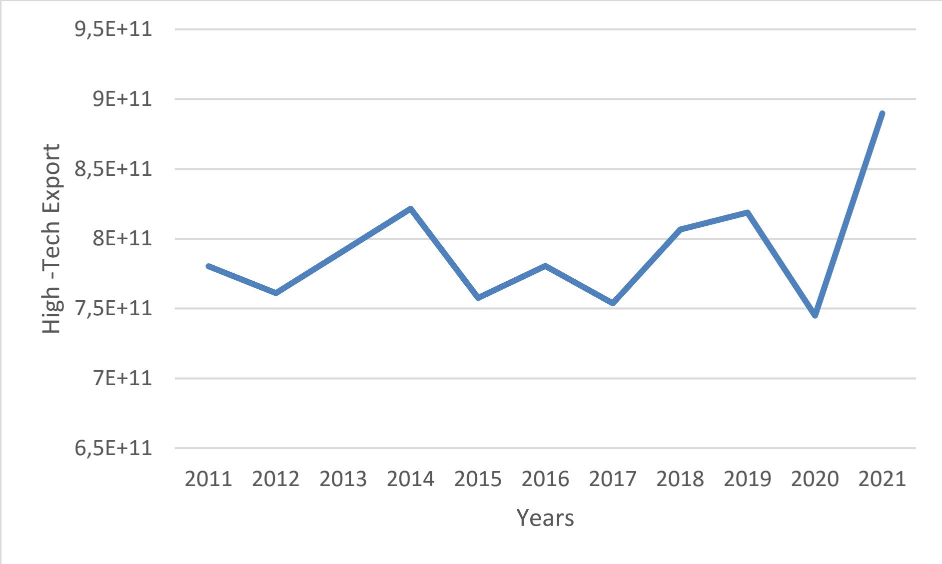


Figure 1: The Development of HTE in Europe
Source: Worldbank (2024)

Figure 1 shows that Europe's HTE follow a volatile path between 2011 and 2020. According to Figure 1, there was no significant increase in HTE from 2011 to 2020. Since 2020, there has been a significant leap in the HTE. The steady state between 2011 and 2020 points to the stagnation of Europe's HTE. The significant decrease between 2019 and 2020 demonstrates the impact of the global recession is due to the Covid-19 pandemic. The sharp increase in HTE after 2020 can be attributed to the effects of deferred demand and inflation resulting from the Covid-19. In conclusion, apart from the structural break in the global market caused by the Covid-19, there has been no significant change in European HTE over the last decade. Although HTE in Europe have not significantly changed in the last decade, the rest of the world, particularly South Asia, has experienced significant growth in this period. Consequently, Europe's share of HTE in the global market has declined over the period. Figure 2 depicts Europe's share of HTE in the global market between 2011 and 2021.

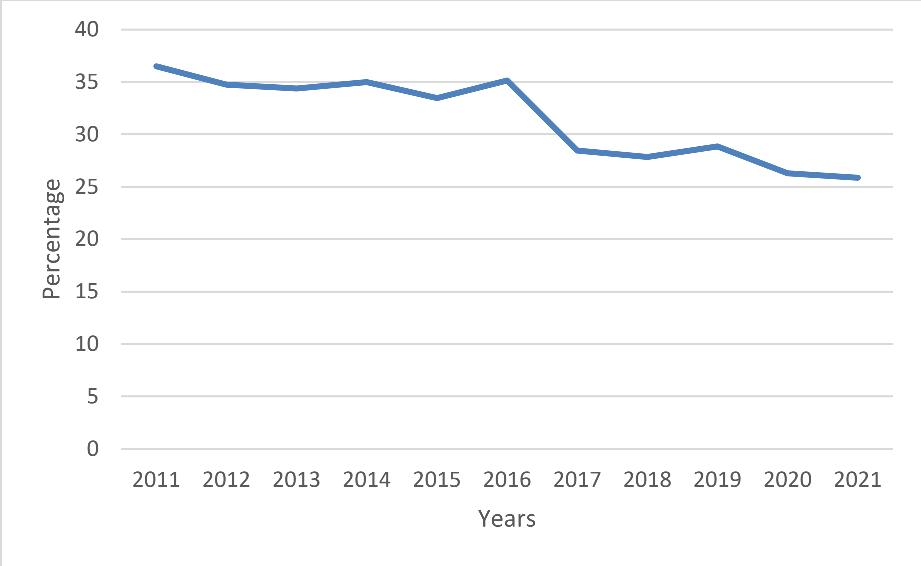
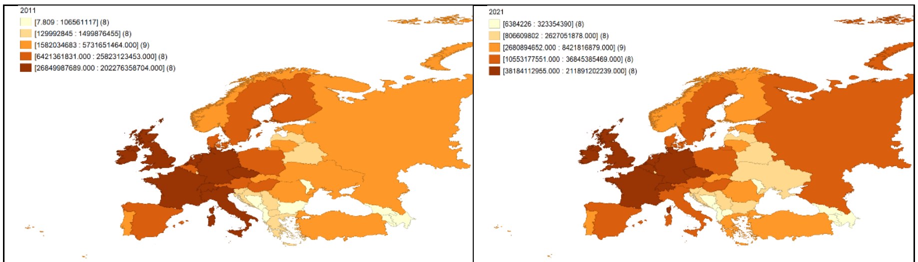


Figure 2: The share of HTE from Europe in the Global Market
Source: Worldbank (2024)

Figure 2 shows that Europe's share of HTE in the global market decreased from 36% in 2011 to approximately 25% in 2021. This decline can be attributed to the rise of HTE in the Southeast Asia region and Europe's stagnation in this sector over the last decade. This information may provide clues to explain the decline in HTE, whether it is experienced in the European continent as a whole or in specific countries. The distribution of HTE across European countries in 2011 and 2021 is shown in Figure 3.



Panel 1: Distribution of HTE in Europe Countries (2011)

Panel 2: Distribution of HTE in Europe Countries (2021)

Figure 3: Distribution of HTE in Europe
Source: Worldbank (2024)

Figure 3 illustrates a heterogeneous distribution of HTE among European countries in 2011, with a notable distinction between the west and east of Europe. It is unsurprising that countries such as England, where the industrial revolution began, and Germany, France, and Italy, where it spread globally, have higher levels of HTE compared to other countries. Furthermore, the reason why Ukraine, Belarus, Georgia, and Azerbaijan, which gained independence after leaving the Soviet bloc, lag behind in HTE compared to other countries can be attributed to the differences in the past political and economic regimes. Figure 3 shows that Eastern European countries and Soviet bloc countries are in the different groups for HTE. This can be expressed by the economic and political structures of the countries, as well as their neighbourhood relationship. The map for 2021 will clarify any changes in the distribution of HTE among countries during the period. Figure 3 shows that, the countries with the highest concentration of HTE did not experience significant changes, except for Italy which fell from the top group to a lower group. Additionally, Ukraine fell to the lower group, while Greece and Bulgaria moved to the upper group in HTE. The decline in Ukraine is attributed to tensions with Russia, while progress in Greece and Bulgaria is attributed to improved relations with the EU. Furthermore, Georgia, Azerbaijan, and Armenia have consistently ranked low in HTE for both 2011 and 2021. These countries share the common characteristics of being former Soviet bloc nations and having close geographical proximity to one another. The geographical proximity of the countries in the top and bottom groups for HTE suggests the existence of spatial spillover in this field.

4. LITERATURE REVIEW

Since the release of Seyoum's seminal paper in 2005, there has been a significant amount of empirical research examining the determinants of HTE. Table 1 presents the summary of the main studies using various econometric methods to investigate the factors affecting HTE in different samples and periods. The results from these studies are mixed due to their sensitivity to the econometric approach and data set used.

Table 1: Literature Review

Author	Period and Sample	Methods	Results
Seyoum (2005)	2000 Developed & Developing Countries	Factor analysis	FDI and national technology infrastructure have a positive impact on HTE.
Srholec (2007)	2001-2003 111 Countries	Two stage OLS	Technological competence, higher education enrolment, patents, and access to computers have a positive effect on HTE.
Braunerjhelm & Thulin (2008)	1981-1999 19 OECD Countries	Panel data models	RDE and FDI have a positive effect on HTE. While education expenditure and government expenditure affect HTE negatively. Also, there is an insignificant relationship between country size and HTE.
Tebaldi (2011)	1980-2008 99 Countries	Panel data models	Human capital, FDI and trade openness have a positive effect on HTE. Also, institutions do not have a significant impact on HTE.
Sara et al. (2012)	2008 120 Countries	Cross-sectional techniques	Innovation capacity have a positive impact on HTE.
Gökmen & Turen (2013)	1995-2011 15 European Countries	Panel cointegration and Granger test	Economic freedom, human capital and FDI have a positive effect on HTE.
Lee & Tang (2013)	1991-2010 OECD Countries	Panel data models	RDE have a positive effect on HTE.
Kılıç et al. (2014)	1996-2011 G-8 Countries	Panel data models and causality test	There is a bidirectional causality relationship between RDE and HTE. In addition, there is a unidirectional causality from HTE to real effective exchange rate.
Sandu & Ciocanel (2014)	2006-2010 26 Europe Union Countries	Panel data models	RDE, FDI, engineer number and sophistication of buyers have a positive impact on HTE.
Şahbaz et al. (2014)	1996-2011 17 Europe Union Countries & Türkiye	Panel cointegration and Granger causality test	There is a bidirectional causality relationship between RDE and HTE.
Kızılkaya, Sofuoğlu & Ay (2017)	2000-2012 12 Developing Countries	Panel data models	FDI, trade openness, economic growth and patents have a positive impact on HTE. However, RDE do not have a significant impact on HTE.

Table 1: Literature Review (continue)

Kabaklarlı, Duran, & Telli Üçler (2017)	1989-2015 14 OECD Countries	Panel cointegration	FDI and patents have a positive impact on HTE. While there is no significant relationship between GDP growth and HTE.
Moraes & Luna (2018)	2005-2015 Latin America & Caribbean Countries	Social network analysis and panel data models	Per capita GDP, schooling and trade openness have an increasing effect on HTE. Also, reel exchange rate, FDI, patents and domestic savings do not have a significant impact on HTE.
Gaur Kant &Verna (2020)	2007-2018 15 developed & developing countries	Panel data models	RDE and gross capital formation affects HTE positively.
Akyol & Demez (2020)	1996-2015 8 new industrialising countries	Regression analysis	Trade freedom, RDE, patents, trademark application and income have a positive impact on HTE. While intellectual property rights do not have an insignificant impact on HTE.
Bayar et al. (2020)	2000-2016 EU Transition Countries	Panel data models	While intellectual property rights and RDE have a positive impact on HTE, FDI have a negative impact on HTE.
Yavuz & Uysal (2020)	1991-2016 15 OECD Countries	Panel data models	RDE have an increasing effect on HTE. However, FDI and economic growth do not have a significant impact on HTE.
Akay (2021)	2007-2018 EU Countries & Türkiye	Cluster analysis	The impact of the patent on HTE is of primary importance, followed by the effect of FDI. RDE have the third-highest level of importance. The final variable is the trade openness.
Kalkan & Pala (2022)	2000-2019 26 High-Middle Income Countries	Panel ARDL	RDE, gross capital formation, trade openness and economic freedom have a positive impact on HTE.

Table 1: Literature Review (continue)

Saraç & Yağlıkara (2022)	1996-2018 25 Developed Countries	Club convergence and panel cointegration	The determinants of HTE vary across the clubs. The impact of economic and cultural globalisation on HTE is more pronounced in clubs with low HTE, while the positive effect of income is more evident in clubs with HTE.
Şanlı & Konukman (2022)	1988-2017 49 Countries	Panel data models	Human capital, RDE, gross capital formation, FDI and reel exchange rate have a positive impact on HTE.
Fonkam (2023)	1995-2017 33 Africa Countries	Dynamic panel data models	The main determinants of HTE are law of rule, human capital, component imports, per capita income, and manufacturing.
Zapata et al. (2023)	2004-2018 35 OECD Countries	Dynamic panel data models	Market size, human capital, FDI, EU membership and physical capital have a positive effect on HTE.

As seen above, the literature on the determinants of HTE clearly divided into two groups. The first group uses cross-sectional techniques, while second group uses panel data techniques. There is limited work in the first group. The second group can be divided into three subgroups based on the sample. The first subgroup comprised countries from the sample without any categorisation. This subgroup includes by Srholec (2007), Tebaldi (2011), Sara et al. (2012), and Şanlı & Konukman (2023). The second subgroup consisted of countries categorized by their level of economic development. Seyoum (2005), Braunerjhelm & Thulin (2008), Le & Tang (2013), Kılıç et al. (2014), Kızılkaya et al. (2017), Kabaklarlı et al. (2017), Gaur et al. (2020), Akyol & Demez (2020), Yavuz & Uysal (2020), Kalkan & Pala (2022), Zapata et al. (2023) is included in this subgroup. The third subgroup contained of countries from the sample classified by geographic location. There are seven studies in this subgroup. Moraes & Luna (2018) preferred Latin American and Caribbean countries, Fonkam (2023) preferred African countries, while the remaining studies preferred European countries as their sample. Among these studies, Gökmen & Turen (2013) focused on selected European countries, while Sandu & Ciocanel (2014), Şahbaz et al. (2014), Bayar et al. (2020), and Akay (2021) focused on the EU sample. The sample of none of studies included all European countries. Also, two different techniques were preferred in the studies. Akay (2021) employed cluster analysis to investigate determinants of high- tech exports, while Gökmen & Turen (2013), Sandu & Ciocanel (2014), Şahbaz et al. (2014), and Bayar et al. (2020) employed panel data models to investigate the determinants of HTE. The literature on the determinants of HTE regarding Europe sample predominantly favours the panel data model. There is no study considering the spatial spillover between European countries in the literature.

Studies have neglected the impact of HTE in the country on HTE in neighbouring countries. In today's world, where information and technology diffuse without regard for space and time, it is important to consider spatial diffusion to avoid biased analysis results. Therefore, unlike the former literature, this study investigates the determinants of HTE in 40 European countries sample by considering the spatial spillover and neighbourhood relationship. This study differs from previous literature in two ways. Firstly, in contrast to prior research, the impact of HTE in Europe is investigated with a more heterogeneous sample of countries. This enables more comprehensive understanding of the subject. Secondly, the application of spatial panel models to investigate HTE allows for the consideration of interactions between geographically proximate countries.

5. DATA AND METHODOLOGY

5.1. Data and Model

We use a balanced panel sample of 40 bordering European countries over the period 2011-2021. Appendix A provides the list of sample countries. Albania, Andorra, Liechtenstein, Monaco, and San Marino are dropped from the empirical analysis due to the lack of data. Iceland was excluded from the empirical analysis as it does not have neighbouring relations with any country. The rationale for choosing the period from 2011 to 2021 is that HTE data are not available prior to 2011 for some European countries, and the latest HTE data is up to 2021. Annual data on export HTE, per capita GDP, resident per capita patent application, RDE, and trade openness were obtained from the WDI. The FDI stock annual data was acquired from UNCTAD. The annual data on economic freedom was collected from Heritage Foundation web sites. Details of the definitions, descriptive statistics and data sources of the variables are presented in Table 2.

Table 2: Summarized Statistics

Variables	Definition	Mean	Std. Dev.	Min	Max	Source
hte	HTE	1.98e+10	3.84e+10	4246458	2.16e+11	WDI (2023)
pgdp	Per capita GDP	26491.980	24643.310	2124.663	110425.9	WDI (2023)
pat	Resident patent application number	3553.570	8453.953	2	48480	WDI (2023)
rd	Per capita RDE	1.01e+10	1.85e+10	1.09e+07	8.57e+10	WDI (2023)

fdi	Foreign direct investment stock	8.04e+09	2.36e+10	8.76e+07	2.42e+11	UNCTAD (2023)
to	Trade openness	2.10e+11	2.94e+11	1.92e+09	1.67e+12	WDI (2023)
ef	Economic freedom index	67.443	8.106	6.500	82	HF (2023)

Notes: Except for the ef variable, the natural logarithm of other variables was taken. WDI: World Development Indicators, UNCTAD: United Nations Conference on Trade and Development

Except for the ef, other variables in the model used logarithmic form. The ef is not expressed in logarithmic form because they are in index form. The functional representation of the model designed to analyse the determinants of HTE is as follows:

lhte= f(lpgd, lpat, lrd, lfdi, lto, ef) (1)

Based on the equation provided, lhte is the dependent variable, while lpgdp, lpat, lrd, lfdi, lto, and ef are independent variable. The methodology section will adapt and extend the above model to incorporate the spatial panel data technique used in the research and form an empirical model.

5.2. Methodology

According to Anselin (1998), all data have spatial correlations and depend on one another. Therefore, a variable in one region is affected by spatial spillover effects from neighbouring regions in addition to being relevant to itself. The spatial structure of economic variables is considered in spatial econometrics. While conventional econometrics typically examines the dependence among observation over time, the spatial econometrics focuses on the dependence among observations across space. It is important to note that spatial econometrics is more than just a two-dimensional version of time series econometrics. One clear distinction is that two geographical can influence one another, whereas two temporal observations cannot. Furthermore, Getis (2007) notes that a range of units of measurement can be employed to model spatial dependence, in contrast to measuring temporal dependence (Elhorst, 2014).

The process of spatial econometrics involves three stages. Firstly, a weight matrix is added to the model and the presence of spatial effect is investigated through OLS model with spatial autocorrelation tests. The most common spatial autocorrelation test to examine the presence of spatial correlation between units is Moran's I test. Moran's I values range from -1 to 1. A positive correlation exists if I>0, while a negative correlation exists if I<0. When I=0, there is no significant interaction exist between the units. Moran's I test can be expressed as (Oanh, 2023):

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}(x_i-\overline{x})^2} \quad (2)$$

In this context, x_i represents the observed value of the ith space unit; $\bar{x}$ denotes the mean of x. the observed values number of space units is represented by n and the normalized spatial weight matrix is denoted by W_{ij}. W_{ij} is crucial in expressing spatial interactions between units. The most employed spatial weight matrices for geographical correlation are typically the geographic adjacency and the inverse distance (Liu et al., 2018). The study's empirical model used a geographic adjacency weight matrix to investigate the spatial interactions. The components of the W_{ij} is as follows:

W_{ij}= {1, if i and j are adjacent; 0, otherwise}

In the second stage of the model, the analysis determines whether a spatial effect is present and, if so, whether it contains spatial lag, spatial error, or both. The Lagrange Multiplier (LM) and robust Lagrange Multiplier tests are widely favoured to identify which spatial effect is present, whether it is spatial lag, spatial error, or both. Based on the outcomes of LM and robust LM tests, the appropriate spatial panel data model is selected. Generally, there are various way for modelling spatial effects. According to Anselin et al. (2008), spatial panel data model captures spatial effects by the spatial lagged dependent variables (SAR) and spatial error term (SEM). In addition to these models, LeSage and Pace (2009) suggested nested alternative models by integrating different roots of spatial links. The best known is the spatial autocorrelation model (SAC), which is a hybrid of SAR and SEM. The construction of SAR, SEM and SAC models is as follows (Simo-Kengne et al., 2024):

$$y_{it}=\alpha+p\sum_{j=1}^{n} W_{ij}\, y_{ij}+\sum_{j=1}^{n} x_{ij}\beta_k+u_{it} \quad (3)$$

with $u_{it}=\lambda W u_{it} + \varepsilon_{it}$

i=1, 2, ……. n; t=1, 2,……..T; y is dependent variable; x is independent variable; W is spatial weight matrix.

If λ=0 model is called SAR

If p=0 model is called SEM

If $\lambda\neq 0$ and $p\neq 0$ model is called SAC

Finally, the empirical model was estimated using the appropriate spatial panel technique and the results were interpreted.

6. RESULTS

The study investigated the determinants of HTE in European countries from 2011 to 2021 using spatial panel analysis. Prior to the analysis, the correlation matrix was used to examine the relationship between the variables and to detect multicollinearity.

Table 3: Correlation Matrices

	lhtech	lpgdp	lpat	lrde	fdi	lto	ef
lhtech	1.000						
lpgdp	0.721	1.000					
lpat	0.733	0.391	1.000				
lrde	0.581	0.812	0.341	1.000			
lfdi	0.414	0.698	0.040	0.457	1.000		
lto	0.914	0.728	0.804	0.554	0.416	1.000	
ef	0.313	0.593	-0.026	0.421	0.570	0.271	1.000

Table 3 shows that HTE are positively related to GDP per capita, patents, RDE, FDI, trade openness and economic freedom. Furthermore, Table 3 reveals a positive relationship between variables, except for the relationship between patents and economic freedom. Table 3 indicates no evidence of multicollinearity among the series. Although correlation matrices provide insights for empirical investigation, they are not sufficient for detecting the relationship between variables. Before conducting spatial panel analysing, non-spatial panel techniques were used that disregard the interdependencies among countries. The non-spatial panel results are presented in Table 4.

Table 4: Non-Spatial Panel Data Results

Variables	**Pooled**		**Fixed Effect**		**Random effect**	
	Coefficient	t stats.	Coefficient	t stats.	Coefficient	t stats.
lpgdp	0.089	0.143	0.701**	2.165	0.624***	2.750
lpat	0.096*	1.861	0.086**	2.136	0.136***	3.765
lrd	0.122**	2.268	-0.158*	-1.806	-0.099	-1.268
lfdi	-0.003	-0.067	-0.026	-0.433	-0.050	-0.919
lto	1.231	15.396	0.709***	4.230	0.881***	7.778
ef	0.018**	2.150	-0.263*	-1.918	-0.028	-0.248
F test	398.700***		24.750***			
R square	0.847		0.273		0.430	
Hausman (chi-square)					10.446***	

Note: *, **, *** denotes %10, %5, %1, respectively.

Table 4 reveals the pooled, fixed effect and random effect estimation results. According to the pooled estimation results, patents, RDE, and economic freedom have a positive impact on HTE. Also, per capita GDP, FDI, and trade openness do not have a significant impact on HTE. Table 2 shows that except for FDI, pooled estimation coefficients align with the correlation matrices. F test results indicate that fixed effects estimators are more appropriate than the pooled estimators. The fixed effect estimation results display that per capita GDP, patents, and trade openness have a positive impact on HTE. Conversely, RDE and economic freedom have a negative effect on HTE. Based on the fixed effect results, there is no significant impact of FDI on HTE. The Hausman test results indicate that random effect estimator is superior to the fixed effect estimator. The analysed sample exhibits a heterogeneous distribution. The results of the F and Hausman tests suggested that random effect estimator is the appropriate choice for the analysis. The random effect estimation results reveal that per capita GDP, patents and trade openness affect HTE positively. RDE, FDI, and economic freedom have an insignificant impact on HTE. Substantial differences exist among the estimations results. To avoid significant inaccuracies in the estimation results, it is crucial to account for unit effects. Neglecting unit effects in the error term, cross sectional dependence and spatial effects can lead biased estimation results. Pesaran CD (2004) test was conducted to evaluate the presence of cross-sectional dependence in the research model based on the optimal estimator (random effects). Results of Pesaran CD (2004) test are reported in Table 5.

Table 5: Cross-Sectional Dependence Test Results

	Pesaran CD Test	
	Test stats.	Prob.
Model	13.043	0.000

Pesaran CD test results indicate that there is cross-sectional dependence problem in the analysis model. Following the identifying cross-sectional dependence problem, the existence of spatial autocorrelation was examined by the Moran's I test, LM test, and robust LM tests. The output of Moran's I test are outlined in Table 6.

Table 6: Moran's I Test Statistic

Year	**Moran I Stat.**
2011	0.567***
2012	0.563***
2013	0.534***
2014	0.542***
2015	0.538***
2016	0.525***
2017	0.519***
2018	0.512***
2019	0.520***
2020	0.515***
2021	0.497***

Note: *,**,*** denotes %10, %5, %1, respectively.

The existence of spatial autocorrelation in the HTE series was analysed by Moran's I test. According to Moran's I test results, a significant spatial effect was observed in the high-tech series for each year between 2011 and 2021. After capturing a spatial autocorrelation in the dependent variable, the empirical model is examined for the existence of it. The LM and robust LM tests is employed to determine whether the spatial autocorrelation is in the form of spatial lag or error. These test results are presented in the Table 7.

Table 7: LM and Robust LM Results

	LM Tests	
	Test Stats.	**Prob.**
LM lag	49.643	0.000
LM error	78.394	0.000
Robust LM lag	3.961	0.047
Robust LM error	32.712	0.000

The LM test results reveal that the null hypothesis which examines the existence of spatial lag and spatial error, has been rejected. After detecting spatial lag and spatial error, robust LM tests conducted. Robust LM test results confirm the LM test results. Based on the LM and robust LM test results, the appropriate model is defined as SAC model. The combination of Hausman test, LM test and robust LM test results point out that the suitable model for the study is the random effect SAC (SACRE). Besides to the SACRE, SARRE and SEMFE results are reported in the Table 8.

Table 8: Spatial Panel Results

Variables	**SARRE**		**SEMRE**		**SACRE**	
	Coef.	t stats.	Coef.	t stats.	Coef.	t stats.
lpgdp	0.463**	2.145	0.581***	2.584	0.497**	2.277
lpat	0.136***	3.869	0.136***	3.947	0.136***	3.913
lrd	-0.108	-1.431	-0.131*	-1.726	-0.121	-1.597
lfdi	-0.801	-1.491	-0.077	-1.400	-0.084	-1.550
lto	0.887***	8.261	0.961***	8.325	0.927***	8.432
ef	0.003	0.817	0.003	0.956	0.003	0.849
λ			0.209***	3.982	0.102	1.101
ρ	0.188***	3.579			0.132*	1.784
R2	0.796		0.816		0.813	
Hausman	4.952		1.815		1.617	
LR	-99.821		-100.792		-99.260	
AIC	241.642		243.584		240.520	
BIC	242.250		244.191		241.128	

Note: *, **,*** denotes %10, %5, %1, respectively.

According to the above table, SARRE test results show that per capita GDP, patent, and trade openness affects HTE positively. Also, RDE, FDI, and economic freedom do not have a significant impact on HTE. The significant and positive spatial lag term aligns with the LM test, robust LM tests and Moran's I test results. This result implies that HTE in the region positively affect HTE in the surrounding regions. Table 8 presents the SEMRE results, which indicate that per capita GDP, patent, and trade openness affects HTE positively, while RDE affects HTE negatively. Moreover, there is not a significant relationship between

FDI and economic freedom with HTE. In addition, the spatial error term coefficient is positive and significant. This results consistent with LM test, robust LM test and Moran's I test results. The significance of both spatial lag and spatial error terms suggest that SACRE is a suitable for the study. Based on the SACRE results, it can be concluded that per capita GDP, patent, and trade openness have a positive impact on HTE. Additionally, it was found that RDE, FDI, and economic freedom do not significantly impact HTE. Table 8 demonstrates that the spatial lag term is significant and positive, while the spatial error term is insignificant. The outcome of SACRE is parallel to that of SARRE.

According to the SACRE results, the primary determinant of HTE is trade openness, followed by the per capita GDP and patents, respectively. The determinants of the HTE vary between non-spatial panel results and spatial panel results. Furthermore, the determinants of the HTE differ according to the consideration of the unit effects. If we did not take into account the unit effects, RDE have a positive impact on HTE. However, the significant effect of RDE on HTE disappears when unit effects are considered. The evidence suggests that the results may be biased if the unit effect and spatial effect are not taken into account.

The results on the positive impact of per capita on high-tech tech exports are in line with the general trend in the literature, such as Kızılkaya et al. (2017), Moraes & Luna (2018), Akyol & Demez (2020). In addition, the positive effect of patents on HTE is aligned with the studies conducted by Srholec (2007), Kızılkaya et al. (2017), Kabaklarlı et al. (2017), Akyol & Demez (2020), Akay (2021). However, Moraes & Luna (2018) contradicts the results of the study. Moraes & Luna (2018) concluded that patents do not have a significant impact on HTE. The variation in results could be attributed to the difference between the sample used in Moraes & Luna' (2018) study and the sample used in our study. The insignificant relationship between RDE and HTE is contrary to the general trend in the literature. Braunerjhelm & Thulin (2008), Le & Tang (2013), Sandu & Ciocanel (2014), Gaur et al. (2020), Akyol & Demez (2020), Bayar et al. (2020), Yavuz & Uysal (2020), Kalkan & Pala (2022), Şanlı & Konukman (2022) have all stated that RDE have a positive impact on HTE. However, our results support Kızılkaya et al.'s (2017) results that there is no significant relationship between RDE and HTE. The reason why RDE does not have a significant effect on high technology may be due to the selection of a more heterogeneous sample compared to the literature. In a sample that includes both developed and developing countries, the effect of RDE on HTE may differ according to the level of development of the countries. While RDE above a particular threshold may not have a significant effect on HTE in developed countries, RDE below a certain particular may have a significant effect on HTE in developing countries.

Landesmenn & Pfaffermayr (1997), attribute this to the fact that increasing RDE may have led to diminishing returns in the economy.

The insignificant relationship between FDI and HTE is concurred with the Moraes & Luna (2018), Yavuz & Uysal (2020). The lack of significant impact of FDI on HTE is contrary to the general trend in the literature, such as Seyoum (2005), Braunerjhelm & Thulin (2008), Tebaldi (2011), Gökmen & Turen (2013), Sandu & Ciocanel (2014), Kızılkaya et al. (2017), Kabaklarlı et al. (2017). The reason of why the lack of significant impact of FDI on HTE could be attributed to the sample characteristics. The research sample comprises developed and developing European countries. As developed EU countries possess the financial capital required for high-tech production and exports, it is not anticipated that FDI will have a positive impact on HTE in these countries. This is supported by Bayar et al.'s (2020) study on EU countries, which found a negative correlation between FDI and HTE. The result of increasing impact of trade openness on HTE is supported by the literature. Tebaldi (2011), Kızılkaya et al. (2017), Moraes & Luna (2018), Kalkan & Pala (2022) argues that trade openness has a positive impact on HTE. There is a limited study for investigating the impact of economic freedom on HTE. The results of this study contradict those of Gökmen & Turen (2013), who reported a positive correlation between economic freedom and HTE. The difference between the outcome and the literature can be explained by the methodology and sample size of study. If we exclude unit effects and spatial effects, we obtain a result parallel to that of Gökmen & Turen (2013). However, it should be noted that Gökmen & Turen (2013) only addressed 15 European countries, making their sample size smaller and more homogenous than ours. Europe's level of economic freedom exceeds the global average. The lack of a significant relationship between economic freedom and HTE may be ascribed to the saturation of economic freedom levels in these countries. Once economic freedom reaches a certain level, it may not significantly contribute to HTE.

7. CONCLUSION

This study examined the determinants of HTE in 40 European countries between 2011 and 2020, using panel data methods. To assess the spatial autocorrelation of HTE series, Moran's I test was conducted. The analysis of the determinants of HTE also incorporated the spatial factor, with the selection of the spatial econometric model based on the LM and robust LM tests. In conclusion, the SAC model with spatial and random effects was adopted for the analysis. The empirical results have led to the identification of several major conclusions and relevant policy recommendations:

Firstly, per capita GDP, patents, and trade openness have an increasing effect on HTE. Whereas, RDE, FDI, and economic freedom do not have a significant effect on HTE. The literature supports the increasing impact of per capita GDP, patents, and trade openness on HTE. However, the lack of a significant effect of RDE, FDI, and economic freedom on HTE contradicts the literature. The reason why the effect of RDE, FDI, and economic freedom on HTE contradicts the literature is attributed to several factors. The contradiction between the study and the literature may be attributed to the sample and method used. The sample of the study comprises of developed and developing European countries. However, the sample of the studies in the literature generally addresses EU countries, OECD countries or homogenous countries sample. The study's results differ from those in the literature, due to the more heterogeneous distribution of the study's sample compared to the samples used in the literature. Furthermore, it is considered that the saturation points of RDE, FDI, and economic freedom in European countries result in these variables having an insignificant impact on HTE. The difference in results from the literature can be ascribed to the use of a spatial panel data method that considers the geographical proximity and interaction between adjacent countries. The reason why the result differs from the literature is the consideration of spatial spillovers to identify the determinants of HTE. This is also supported by the fact that the non-spatial panel results differ from the spatial panel results. The positive effect of patents, one of the indicators of innovation, on HTE is evident. However, RDE do not have a significant impact on HTE. This suggests that knowledge for commercialisation play a crucial role in accelerating HTE.

Secondly, the results of Moran's I test, LM test, and robust LM test indicate the presence of spatial dependence in the model. Additionally, the SACRE results show a significant and positive spatial lag term, which is supported by the aforementioned tests. This suggests that the HTE of a country are positively influenced by the HTE of its surrounding countries. Based on the results, primary contribution of study to the literature is to consider spatial spillover across European countries when determining HTE. The secondary contribution is to demonstrate the extent to which the determinants of HTE differ between heterogeneous and homogeneous European countries samples.

Various recommendations are offered to policy makers and researchers in line with the results. To regain their share of the global market in HTE, Europe that have lost a significant portion over the last decade should eliminate trade barriers with other countries and commercialise knowledge. Furthermore, to expedite the HTE, policies aimed at increasing per capita income should be formulated. To examine this issue, future researchers could use the club convergence technique to divide European countries into different groups based on their level of technology exports. They could then analyse how the determinants of HTE vary between these groups. Also, researchers should analyse the determinants of HTE on a country-by-country basis using the GTWR method that takes into account the spatial effect. This analysis would provide evidence on whether European countries have a homogeneous or heterogeneous distribution of HTE.

8. CONFLICT OF INTEREST STATEMENT

There is no conflict of interest between the authors.

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10. AUTHOR CONTRIBUTIONS

AR: Idea;
AR, ES: Design;
ES: Inspection;
AR, ES: Collection and/or processing process;
AR: Analysis and Interpretation;
AR, ES: Literature Review;
AR, ES: Written;
ES: Critical Review

11. ETHICS COMMITTEE STATEMENT AND INTELLECTUAL PROPERTY COPYRIGHTS

Ethics committee approval is not required for the study.

12. REFERENCE

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13. APPENDIX

a. Sample Countries

Armenia	Estonia	Lithuania	Russia
Austria	Finland	Luxembourg	Serbia
Azerbaijan	France	Moldova	Slovak Republic
Belarus	Georgia	Montenegro	Slovenia
Belgium	Germany	Netherlands	Spain
Bosnia	Greece	North Macedonia	Sweden
Bulgaria	Hungary	Norway	Switzerland
Crotia	Ireland	Poland	Türkiye
Czechia	Italy	Portugal	Ukraine
Denmark	Latvia	Romania	United Kingdom