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SPATIAL ANALYSIS OF HIGH-TECH EXPORTS WITH GEOGRAPHICALLY WEIGHTED REGRESSION

COĞRAFİ AĞIRLIKLI REGRESYON İLE YÜKSEK TEKNOLOJİ İHRACATININ MEKANSAL ANALİZİ

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Abstract

The development of High-Technology Exports (HTE) contributes to the increase of competitiveness and growth in national production, the development of commercial and economic cooperation with foreign countries, and the diversification of the economy. In addition, high technology exports reduce the current account deficit of the country's economy. Therefore, high-tech industries have become indispensable for economic development in a country. The aim of this study is to examine the existence of spatial (neighbourhood) relations of countries in high-technology exports. In this study, Exploratory Regression analysis was applied to determine the model that best explains HTE among the variables. Moran Index was used for spatial autocorrelation, Geographical Weighted Regression (GWR) method for spatial regression analysis, and Ordinary Least Squares (OLS) method, to compare with the GWR method. The GWR model established in this study showed that countries have a weak or strong spatial relationship with their neighboring countries in terms of HTE. It has been observed that this spatial relationship is strong in the countries neighboring China, which ranks first in HTE, while the spatial relationship is weak in countries where HTE is low.

Keywords: High Technology Export, Geographic Information Systems, Moran Index, Geographically Weighted Regression.

Öz

Yüksek teknoloji ihracatının (YTİ) geliştirilmesi, ulusal üretimde rekabet gücünün ve büyümenin artmasına, yabancı ülkelerle ticari ve ekonomik işbirliğinin genişlemesine ve ekonominin çeşitlendirilmesine katkıda bulunur. Ayrıca yüksek teknoloji ihracatı ülke ekonomisinin cari açığını azaltmaktadır. Bu nedenle yüksek teknoloji endüstrileri, bir ülkedeki ekonomik gelişme için vazgeçilmez hale gelmiştir. Bu çalışmanın amacı, yüksek teknoloji ihracatında ülkelerin mekânsal (komşuluk) ilişkilerinin varlığını incelemektir. Çalışmada değişkenler arasında YTİ'yi en iyi açıklayan modeli belirlemek için keşifsel regresyon analizi uygulanmıştır. Mekansal otokorelasyon için Moran İndeksi, mekansal regresyon analizi için Coğrafi Ağırlıklı Regresyon (CAR) yöntemi ve CAR yöntemi ile karşılaştırmak için Sıradan En Küçük Kareler (SEKK) yöntemi kullanılmıştır. Bu çalışmada kurulan CAR modeli, ülkelerin komşu ülkeleriyle YTİ açısından zayıf veya güçlü mekansal ilişkiye sahip olduğunu göstermiştir. YTİ'de ilk sırada yer alan Çin'e komşu ülkelerde bu mekansal ilişkinin güçlü olduğu, YTİ'nin düşük olduğu ülkelerde ise mekansal ilişkinin zayıf olduğu gözlemlenmiştir.

Anahtar Kelimeler: Yüksek Teknoloji İhracatı, Coğrafi Bilgi Sistemi, Moran İndeks, Coğrafi Ağırlıklı Regresyon.

GENİŞLETİLMİŞ ÖZET

Çalışmanın Amacı

Bu çalışmanın amacı, AR-GE harcamaları, doğrudan yabancı yatırım net girişler, brüt yüksek okullaşma, patent başvuruları, ticari açıklık, insani gelişim indeksi, ekonomik özgürlük indeksi faktörleri ile yüksek teknoloji ihracatı (YTİ) arasındaki mekansal (komşuluk) ilişkilerinin varlığını 130 ülke düzeyinde incelemektir.

Araştırma Soruları

Çalışmada şu soruların cevapları aranmıştır: Yüksek teknolojili ürün ihracatını etkileyen faktörler nelerdir? YTİ üzerinde etkili olan belirleyici faktörler nasıl bir etkiye sahiptir? Ülkeler arasında YTİ açısından mekansal bir ilişki var mıdır? Oluşturulan coğrafi ağırlıklı regresyon (CAR) modeli sayesinde tahmin edilen YTİ tutarları ile gerçek tutarları arasında benzerlik var mıdır?

Literatür Araştırması

Ulusal ve uluslararası literatür incelendiğinde YTİ'nin belirleyicileri üzerine yerli ve yabancı çok sayıda çalışmanın olduğu görülmektedir. Bu çalışmalarda; doğrudan yabancı yatırımlar, talepkar yerel alıcılar, ileri teknolojik altyapı, Ar-Ge harcamaları, insan kaynakları, uluslararası ticaret açıklığı, hukukun üstünlüğü, ithalat, brüt sermaye oluşumu, GSYİH, bilgi ve iletişim teknolojileri gelişim indeksi YTİ'yi etkileyen faktörler olarak belirlenmiştir. Literatürde YTİ'nin mekansal ilişkisini araştıran hiçbir çalışmaya rastlanılmamıştır. Bu açıdan çalışmanın literatüre katkı sağlaması beklenmektedir.

Yöntem

Çalışmada öncelikle 130 ülkenin yüksek teknoloji ihracatını en iyi açıklayan değişkenleri belirlemek için keşifsel regresyon analizi uygulanmıştır. Keşifsel regresyon analizi sonucunda belirlenen değişkenlerin mekânsal otokorelasyonu için Moran I analizi, mekânsal regresyon analizleri için CAR yöntemi ve CAR yöntemi ile karşılaştırmak için sıradan en küçük kareler (OLS) yöntemi kullanılmıştır. Bu analizler için ArcGIS Pro programı kullanılmıştır.

Sonuç ve Değerlendirme

Araştırma kapsamındaki ülkelerde AR-GE harcamaları, doğrudan yabancı yatırım net girişleri, patent başvuruları, ticari açıklık ve ekonomik özgürlük indeksi, YTİ üzerinde pozitif etkiye sahipken brüt yüksek okullaşma ve insani gelişim indeksi ise negatif etkiye sahiptir. OLS ile CAR yöntemleri karşılaştırıldığında CAR yönteminin model performansının daha yüksek olduğu görülmüştür. CAR analizi ile hesaplanan lokal R2 değerleri yani bağımsız değişkenlerin YTİ'yi mekansal olarak açıklama oranları 0,8635 ile 0,9075 arasında değişmektedir. Lokal R2 değerlerinin haritanın güney-doğusundaki ülkelerde en yüksek olduğu ve Kuzey Amerika kıtası hariç doğudan batıya doğru azaldığı görülmüştür. CAR analiziyle hesaplanan YTİ'nin tahmini değerleri ile gözlemlenen değerlerinin de birbirine yakın oldukları tespit edilmiştir. Bu çalışma ile ülkelerin katma değeri yüksek teknolojik ürünlerini artırdıkça komşu ülkelerle ihracat ilişkilerini de güçlendirdiği sonucuna varılmıştır.

1. INTRODUCTION

World economies have developed comprehensively thanks to foreign trade and leading-edge technology. In terms of foreign trade, exports also provide the foreign currency necessary for the import. Theoretical and empirical argumentum show that there is a positive relation between foreign trade and economic boost. Alike, exports play an important role in facilitating enterprise and technology transfer, which expedites the globalization process. High-tech industries generate many of the new products, new processes, and inventions that enable firms to access new markets (Sultanuzzaman et al., 2019).

Today, technological innovation provides a significant competitive advantage and is gradually seen as the propulsive force of the contemporary economy. In this direction, information and technology are now accepted as the basic components underlying the competitive capacity of countries, regions, sectors and firms and become vital factors that determine the position of a country in international trade. Therefore, the information improving abilities of economies are more and more associated with innovation systems, taking place permanently within these systems and becoming one of the key precedences of policy agendums across the world (Cooke et al., 2004).

Novelties in the product or production process are generally considered to occur as a result of research and development (R&D) activities. In developed and industrialized countries, companies devote large sums to R&D in order to compete in international trade. It is seen that developing countries are dependent on technologically developed countries and imported technologies are the originary sources of innovation. However, new researches show that emerging industries like China and India are developing their own technologies and trying to become free from technologically advanced countries. (Millmana et al., 2012).

The theoretical foundation of high-tech exports can be explained through different approaches in international economic theory. The most important of these theories are the Heckscher-Ohlin theory and the New International Trade Theory. The Heckscher-Ohlin theory attempts to explain which products a country will produce and export based on the differences in the factors it possesses (such as capital, labor, and land). Factor abundance demonstrates its superiority among countries through labor force, capacity for innovation, natural resource richness, and relative abundance of production factors. According to Heckscher and Ohlin, countries engage in foreign trade due to their distinct factor abundances. According to this theory, a country's production and export of high-tech products is associated with an increase in capital-intensive production. The New International Trade Theory, on the other hand, attempts to explain the factors that provide a competitive advantage, particularly in the trade of new products. Countries that can rapidly implement new goods or production technologies in their own economy and consistently push new products into foreign markets can achieve lasting success in foreign trade. According to this theory, a country must innovate and achieve economies of scale in the production of these products in order to gain a competitive advantage in high-tech product exports (Öztürk, 2003).

The extents of rivalry have changed with the new economic system, and in the new economic system, international rivalry is called with names such as "digital economy", "high-tech economy", "information technology economy", "knowledge-based economy" or "network economy" (Meral, 2019).

Among researchers, economists and analysts, two factors stand out for expanding economic growth and prosperity: human resources and technological change. With the structural change and rapid growth in high technology, the effect of HTE on economic output is increasing.

2. LITERATURE OF HIGH-TECH EXPORT DETERMINANTS

Human resources, natural resources, technological development, social and political factors are the main determinants of economic output. Today, technological development provides the most important contribution to the country's economy (Satrovic, 2018).

The concept of high technology is generally defined as the most advanced technology applied to produce technologically advanced, complex, feature-packed products that require high R&D expenditures (Keeble & Wilkinson, 2000). High-tech industries are industries that produce high-tech products. High technology products consist of the sum of products in the Aerospace, Electronic-Telecommunication, Computer-Office machinery, Scientific Instruments, Pharmacy, Electrical Machines, Chemistry, Non-Electrical Machinery and Defense sectors with high R&D intensity classified according to Standard International Trade Classification Revision 4 (World Bank, 2022).

With the effect of globalization, it is important for countries to increase their sophisticated and technology-intensive exports with high added value in order to compete in export markets and achieve sustainable growth performance (Güneş & Akın, 2019). Today, where high technology exports are so important for countries, it is also so important to determine the factors that determine or affect the high technology exports (HTE). In this context, many studies in the literature have been conducted on the determining factors of HTE. Research and Development (Seyoum, 2005; Braunerhjelm & Thulin, 2008; Falk, 2009; Vogiatzoglou, 2009; Gökçe et al., 2010; Gaur et al., 2020), foreign direct investment (Kabaklarli et al., 2018; Garces & Adriatico, 2019), gross higher enrolment (Srholec, 2006; Sarker et al., 2016; Vinces & Audretsch, 2021), number of researchers in R&D (Vogiatzoglou, 2009; Alemu, 2012; Yaman et al., 2020), patent applications (Meo & Usmani, 2014; Kabaklarli et al., 2018, Akar & Topoğlu, 2022), gross capital formation (Kabaklarli et al., 2017; Wabiga & Nakijoba, 2018), trade openness (Tebaldi, 2011; Kizilkaya et al., 2016; Güneş et al., 2020), human development index (Gökmen & Turen, 2013; Muslija et al., 2018), economic freedom index (Ferragina & Pastore; 2007; Gökmen & Turen, 2013) were determined as some factors explaining HTE in the studies. In our study, using these factors, Geographically Weighted Regression (GWR), one of the analysis techniques of Geographic Information Systems (GIS), was used to analyze the spatial relations of countries in HTE.

3. GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Information systems are assembly of hardware, software, and communication networks that people create and use to pick up, constitute, and scatter beneficial data to support deciding, coordination, control, analysis, and visualization in enterprise environments (Laudon & Laudon, 2012).

There are many types of information systems spread over a wide scope. One of the basic information systems used in these types is geographic information systems. GIS is a software system used to capture, process, store, control, display and protect spatial data about locations on the surface of the world. By correlating seemingly unrelated data, GIS helps to better understand spatial patterns and relations. GIS has a structure that can be applied in any area where spatial information is available. With the new developments in technology, GIS, which includes many applications, has expanded its use in areas such as education, health, insurance, production, oil and pipeline, security, real estate, retail, telecom, transportation, electricity and gas infrastructure, natural resources, water management (GIS Lounge, 2022).

One of the strengths of GIS is that it can perform spatial analysis, that is, it can analyze spatial relationships. One of the most frequently used spatial analysis methods is Geographical Weighted Regression (GWR).

GIS has become an integral part of many industries. GIS is expected to continue its phenomenal growth in the coming years as it unravels the complexity of spatial data and local geographies. As the need to collect and analyze spatial data grows, GIS will become even more important to businesses and governments.

4. METHODOLOGY

4.1. Study Field and Data Set

According to the United Nations, there are a total of 206 countries in the world, 193 of which are member states, 2 are observer countries and 11 are in the category of other states. 130 countries could be included in this study due to the availability of data. These countries within the scope of the research; Germany, USA, Angola, Argentina, Albania, Australia, Austria, Azerbaijan, Bahrain, Western Samoa, Belize, Belgium, Benin, Belarus, United Arab Emirates, United Kingdom, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei, Bulgaria, Burkina Faso, Burundi, Czech Republic, China, Denmark, Dominican Republic, Ecuador, El Salvador, Indonesia, Armenia, Estonia, Ethiopia, Morocco, Fiji, Ivory Coast, Finland, France, Gambia, Ghana, Guatemala, South Africa, South Korea, Cyprus, Georgia, India, Netherlands, Honduras, Croatia, Iran, Ireland, Spain, Israel, Sweden, Switzerland, Italy, Iceland, Jamaica, Japan, Cambodia, Cameroon, Canada, Montenegro, Kazakhstan, Kenya, Colombia, Comoros, Congo, Costa Rica, Kuwait, Kyrgyzstan, Latvia, Lithuania, Lebanon, Luxembourg, Hungary, Madagascar, Macedonia, Malaysia, Mali, Malta, Mauritius, Mexico, Moldova, Mozambique, Mongolia, Myanmar (Burma), Egypt, Namibia, Nepal, Niger, Nigeria, Nicaragua, Norway, Central African Republic, Uzbekistan, Pakistan, Paraguay, Peru, Poland, Portugal, Romania, Rwanda, Russia, Senegal, Seychelles, Singapore, Slovakia, Slovenia, Sudan, Saudi Arabia, Swaziland, Serbia, Chile, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Turkey, Uganda, Ukraine, Uruguay, Jordan, Vietnam, New Zealand, Greece, Zambia, Zimbabwe.

Most of the data are taken from the World Bank database. The year 2019 was considered for analysis in the database. While the Economic Freedom Index data is taken from The Heritage Foundation site; The Human Development Index was taken from The United Nations Development Program Human Development Reports website.

4.2. Introduction of Parameters

When the relevant literature is scanned, most of the variables used in studies investigating the factors affecting high technology exports are brought together in this study. Accordingly, the variables used in this study are given in Table 1.

Table 1. Variables Table

Dependent Variable	**Code**	**Explanation (Reference)**
High Technology Export	DV	Data available, in US dollars (https://data.worldbank.org/)
Independent Variables	**Code**	**Explanation (Reference)**
R&D Expenditures	V1	% of Gross Domestic Product (https://data.worldbank.org/)
Foreign Direct Investment Net Inflows	V2	% of Gross Domestic Product (https://data.worldbank.org/)
Gross College Enrolment	V3	Number of students enrolled in higher education / Population of higher education age (https://data.worldbank.org/)
Researcher in R&D	V4	Per Million People (https://data.worldbank.org/)
Patent Applications	V5	World patent applications filed with the national patent office or through the Patent Cooperation Treaty (https://data.worldbank.org/)
Gross Capital Formation	V6	% of Gross Domestic Product (https://data.worldbank.org/)
Commercial Openness	V7	(Export + Import) / Gross Domestic Product (https://data.worldbank.org/)
Human Development Index	V8	Represents the measurement consisting of education, literacy and income components and these components are averaged (https://hdr.undp.org/en/data)
Economic Freedom Index	V9	It is obtained by averaging the 12 economic freedom factors (https://www.heritage.org/index/)

4.3. Method of Study

In this study, Exploratory Regression analysis was applied to determine the model that best explains high technology exports among the variables given in Table 1, before creating the spatial relationship maps of high technology exports of 130 countries. Moran Index was used for spatial autocorrelation of the variables determined by exploratory regression analysis, GWR method for spatial regression analysis, and Least Squares (OLS) method, which is one of the basic regression methods, to compare with the GWR method. ArcGIS Pro program was used for these analyses.

4.3.1. Exploratory Regression Analysis

Exploratory regression analysis evaluates all probable combinations of candidate explanatory changeables and looks for linear regression models that best explain the dependent variable. The analysis results are given in Table 2.

Table 2. Exploratory Regression Results

Model	Adjusted R^2	AICc	VIF	Variables in the Model
1	0.875454	6612.535125	2.111746	+V1 +V2 -V3 +V5 +V7 -V8 +V9
2	0.874463	6614.844135	2.971364	+V1 +V2 -V3 +V4 +V5+V7-V8 +V9
3	0.874475	6614.832275	2.117831	+V1 +V2 -V3 +V5 -V6 +V7 -V8 +V9

According to the exploratory regression results, the independent variables that best explain High Technology Exports with a rate of 87.54% are R&D Expenditures (V1), Foreign Direct Investment Net Inflows (V2), Gross College Enrolment (V3), Patent Applications (V5), Trade Openness (V7), Human Development Index (V8) and Economic Freedom Index (V9). Researcher in R&D (V4) and Gross Capital Formation (V6) variables were excluded from the model. The lower the Akaike Information Criteria (AICc) value, the better the model performs. Variance Inflation Factor (VIF) measures the strength of the relationship between independent variables. The higher the VIF value, the stronger the connection between independent variables, and the less reliable the linear regression model becomes. Multicollinearity can lead to inaccurate estimation of regression coefficients and exaggeration of the standard errors of regression coefficients. Multi-equivalence can render a model unstable when the VIF value is higher than about 7.5 (ArcGIS Exploratory Regression, 2022). Since AICc and VIF values were the lowest among all combinations, the variables in Model 1 were selected and analyses were made according to these variables.

4.3.2. Spatial Autocorrelation

The Moran Index (I) method is one of the preferred and frequently used measures in the investigation of spatial autocorrelation. Moran I spatially evaluates the model of a dataset and determines whether the feature is scattered, clustered, or random based on their positions and values. The Moran Index takes values between +1 and -1. Values ranging from 0 to +1 show a positive correlation and spatially clustering. Values ranging from -1 to 0 show a negative correlation and spatially scattering. If the value is equal to zero, it indicates that there is no spatial correlation (Kumari et al., 2019). Moran I value is calculated by the equation given below:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S_0\sum_{i=1}^{n}(x_i-\bar{x})^2} \qquad S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \tag{1}$$

Here x_i and x_j are variable values at positions i and j, w_{ij} is spatial weight between i and j positions, n is the count of spatial units and S_0 is the sum of all spatial weights. Given the overall variance of the values in the dataset, the z-score and p-value should be calculated to indicate whether the spatially variation is statistically significant.

$$Z_I = \frac{I-E(I)}{\sqrt{Var(I)}} \qquad E(I) = (-1) / (n-1) \qquad Var(I) = E(I^2) - E(I)^2 \tag{2}$$

In these formulas I; Moran's index value, E(I); its expected value, Var(I); I variance and n; represents the number of units.

After examining the Moran Index's z-score and p-value, final conclusions are drawn about the observed pattern. If the z-score is greater than +1.96 or less than -1.96 at the 95% confidence level, Moran's Index shows that it is statistically significant, that is, there is also spatial autocorrelation (Yang et al., 2018).

4.3.3. Geographically Weighted Regression (GWR)

Geographically Weighted Regression is a statistical method that measures the strength and aspect of relations between a explained spatial variable and explanatory spatial variables, taking into account the position of each observation (IGI Global Dictionary, 2022). GWR is a spatial data analysis method developed by adding spatial weights to traditional regression. GWR is a method that investigates spatial diversity. The spatial diversity shows that there is a different correlation between the explained and explanatory variables at each point due to the dependence of the model parameters on the point (geographic coordinates) (Kashki et al., 2021). The equation of the GWR model is as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \tag{3}$$

(u_i, v_i) are the latitude and longitude coordinates of the *i* location, y_i is explained variable at position *i*, x_{ik} are explanatory variable at position *i*, $\beta_k(u_i, v_i)$ is the regression coefficient for the explanatory variable *k* at position *i*, $\beta_0(u_i, v_i)$ is the constant variable of the model at position *i*, and ε_i represents the error term. In order to find the β coefficients, their weights must also be calculated. In GWR, an observation is weighted by its affinity to the *i* position. Data from observations closer to *i* are weighted more than data from observations further away (Fotheringham et al., 2002).

Neighborhood weights in the weight matrix are found with the help of Gaussian or Bi-Square kernel functions. In order to calculate any of these functions, the optimal spatial bandwidth must be determined. For optimal bandwidths, one of the cross validation (CV) or Akaike Information Criterion (AICc) methods is usually used. Kernel functions also need to determine the remoteness between the regression point and the reference points. This distance is usually determined by the Euclidean distance method. As a result of all these processes, geographically weighted regression coefficients are calculated. Thanks to these regression coefficients, the estimated value of the regression point is calculated.

5. FINDINGS

5.1. Descriptive Findings

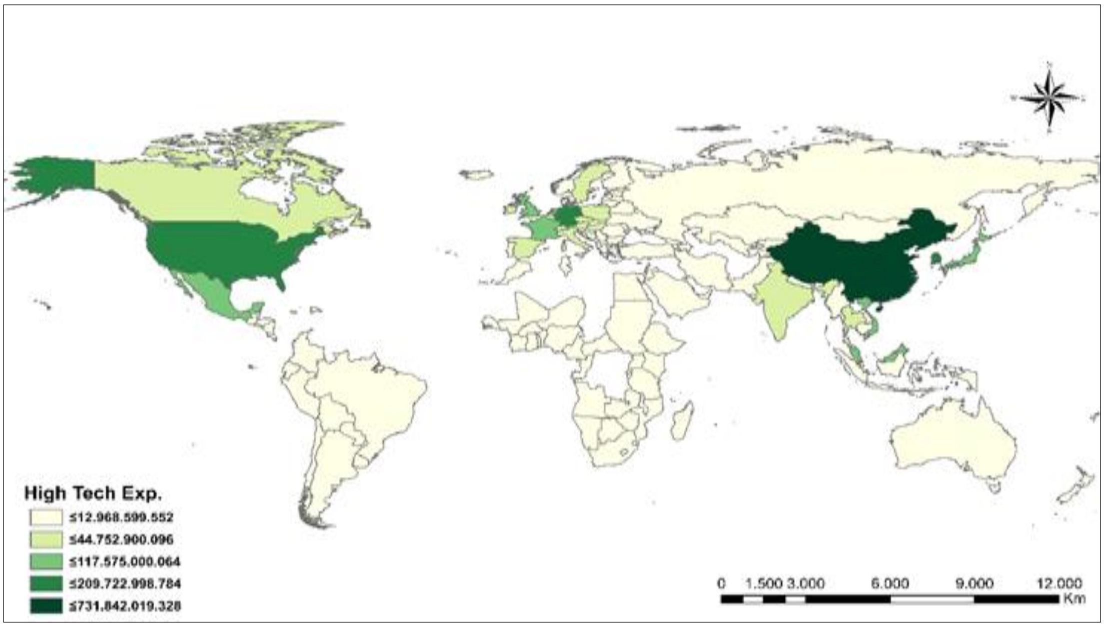
The maximum, minimum, mean and standard deviation values of the data of the dependent and independent variables of 130 countries around the world in 2019 used in the study are presented in Table 3.

Table 3. Raw Data of Variables

Variables	Max.	Min.	Mean	Std. Dev.
R&D Expenditures	4.941	0.029	0.892	0.995
Foreign Direct Investment Net Inflows	30.097	-40.291	2.022	7.982
Gross College Enrolment	142.852	2.223	45.509	30.614
Patent Applications	1,393,815	1	19,938.538	134,256.513
Commercial Openness	3.601	0.013	0.895	0.541
Human Development Index	0.956	0.391	0.747	0.148
Economic Freedom Index	88.800	44	63.388	9.325
High Technology Export	731,842,123,479	6,066	19,587,851,611	72,606,842,916

Thematic (density) map of the High-Tech Export variable of 130 countries examined by the ArcGIS Pro program was created using the Jenks Natural Breaks (JNB) classifying technique. Based on the natural classifications found in the data, the JNB method reduces the within-class variance as much as possible, while increasing the variance between classes as much as possible. The thematic map created by this method is given in Figure 1.

Figure 1. HTE Thematic Map of Countries



With the JNB method, countries are separated into 5 classes as Very High, High, Medium, Low, Very Low with the natural breaks of HTE data. According to this classification, as the HTE of countries increase on the map, the color tone gets darker. In other words, while the countries with the darkest color tone classification are the countries with the highest HTE, the countries with the lightest color tone classification are the countries with the lowest HTE. In Table 4, the list of countries according to HTE in 2019 is given.

Table 4. HTE Country List

Classes	Countries
Very High	China
High	Germany, South Korea, Singapore, USA
Medium	France, Japan, Malaysia, Netherlands, Vietnam, UK, Mexico
Low	Thailand, Ireland, Czech Republic, Italy, Canada, Switzerland, Belgium, Poland, India, Hungary, Sweden, Austria, Spain
Very Low	Remaining 105 countries

In Table 4, the countries in each class are given in order of HTE from largest to smallest. By far, China is the only country in the category with a very high HTE. There are 4 countries in the high class, 7 in the middle class, 13 in the lower class and 105 in the very low class. There are only 12 countries in the world whose HTE are above the middle level, and the country with the largest share among them is China. The sum of the HTE of 121 countries from 130 countries within the scope of the study could not reach the HTE figure of China. Even with China's closest rival, Germany, there is a huge difference of about 520 billion dollars.

5.2. Comparison of OLS and GWR Analyzes

Ordinary Least Squares (OLS) is the beginning of spatial regression analysis and is the most widely used regression technique. OLS creates a global model of the relationship between variables and expresses this relationship with a single mathematical equation. GWR, on the other hand, creates a local model to represent the relationship between variables and evaluates it by fitting a regression equation for each unit in the dataset. In other words, it generates regression equations for each unit separately.

Before performing the GWR analysis, which takes into account spatial differences, comparison with the OLS method, one of the regression techniques, is useful in testing the reliability of the GWR analysis. Akaike's Information Criterion (AICc) and Adjusted R^2 values of OLS and GWR analysis results are given in Table 5.

Table 5. OLS and GWR Results

	OLS	**GWR**
R^2	0.8822	0.8892
Adjusted R^2	0.8754	0.8795
Akaike Information Criteria	6612.5351	6607.5928

While the R^2 and especially the adjusted R^2 values, which show the performance of the established model, were 0.8754 according to the least squares method in 2019, this value increased to 0.8795 according to the GWR method. According to the GWR method, this value shows that the independent variables explain the dependent variables at a high rate of 87.95%. When the AICc values are compared in Table 4, since the value of GWR is smaller than the value of OLS, the fit performance of the GWR model is higher. According to these results, it was preferred to use the GWR model, which explains the relationship between the variables, taking into account the spatial differences. According to the United Nations, there are a total of 206 countries in the world. However, the established GWR model could be applied to 130 countries due to the availability of data. The general model of the 2019 geographically weighted regression for the dependent and independent variables of HTE has been established as follows:

$$HTE_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)x_{1i} + \beta_2(u_i, v_i)x_{2i} + \beta_3(u_i, v_i)x_{3i} + \beta_4(u_i, v_i)x_{4i} + \beta_5(u_i, v_i)x_{5i} + \beta_6(u_i, v_i)x_{6i} + \beta_7(u_i, v_i)x_{7i} + \varepsilon_i \quad (7)$$

HTE_i: HTE of country in position i. (u_i, v_i): latitude and longitude coordinates of location i. x_{ki}: k arguments of country at position i. $\beta_k(u_i, v_i)$: the regression coefficient for the independent variable k of the country at position i. $\beta_0(u_i, v_i)$: constant variable of the model at position i. ε_i: error term at position i.

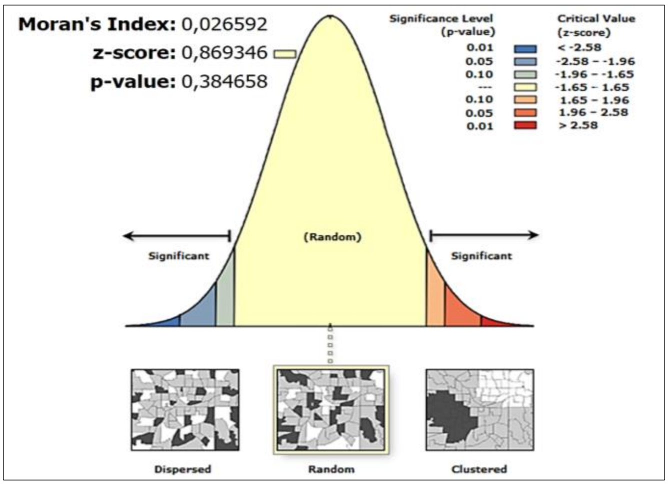
According to the created GWR model, Kernel type and Bandwidth methods should be determined in the analysis process of the data. The adaptive function type was chosen for analysis because it can adapt itself in size to changes in data density. The Akaike Information Criterion (AICc) has been chosen because it can derive the optimal bandwidth by providing a balance between the goodness of fit and degrees of freedom within the bandwidth.

5.3. Moran I Analysis Results

For a well-defined geographically weighted regression model, the regression residuals should show a spatially random distribution. In other words, the distribution of residual values should not show spatial autocorrelation (Aydın et al., 2018; ArcGIS Interpreting GWR results, 2022).

Moran’s I analysis was performed on the regression residuals to ensure that the residuals were spatially random. Moran I analysis findings and graphical results of the standardized residues obtained as a result of the GWR analysis are presented in Figure 2.

Figure 2. Moran I Results of Standardized Residues

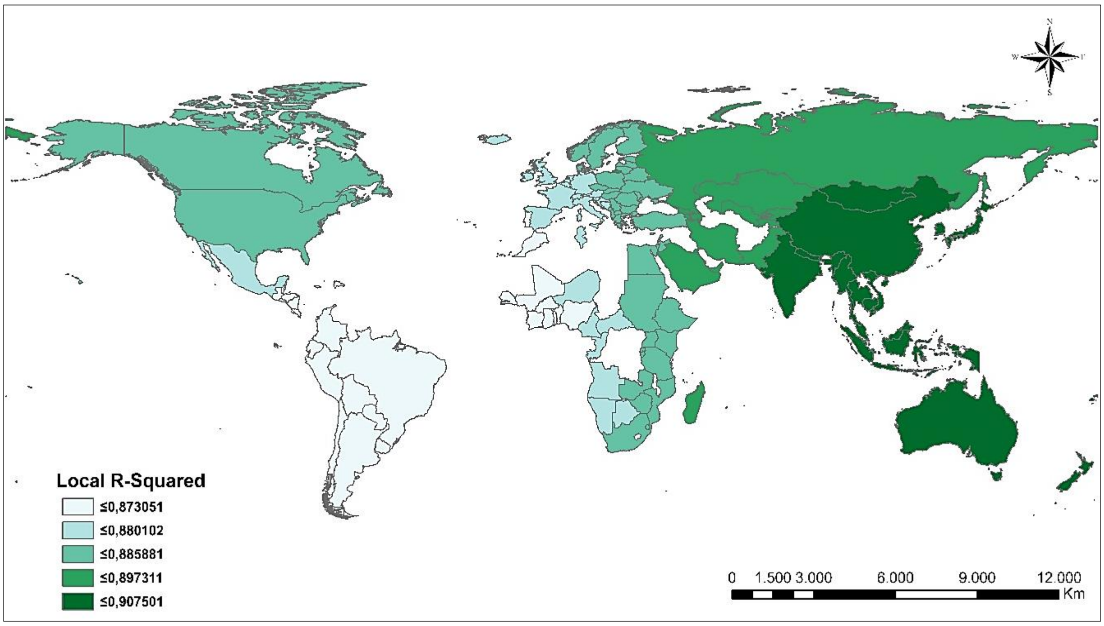


According to Figure 2, since the p-value of the standardized residuals of the GWR model was greater than 0.05 at the 95% confidence interval, it was found that it was not statistically significant, that is, there was no spatial relationship in the distribution of the residuals. In other words, since the z-score is between -1.65 and +1.65 threshold values, the standard residuals are spatially randomly distributed with a probability of 38.4%. These results show that the established model is strong, that is, well-defined.

5.4. Thematic Maps by GWR Analysis

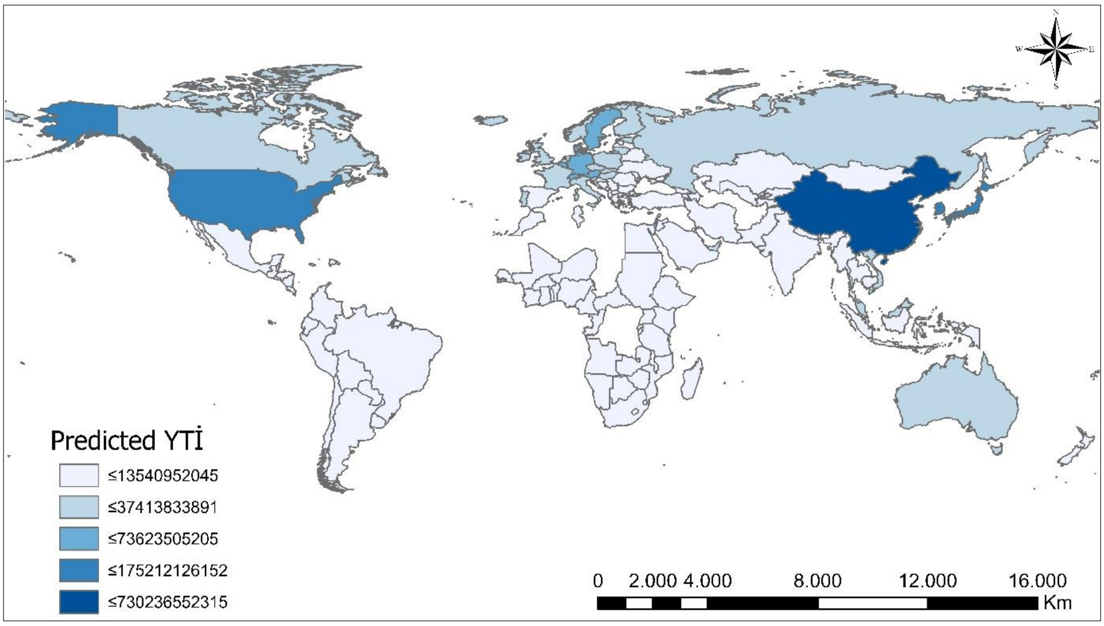
Local R^2 indicates how well the local regression model constructed with GWR fits the surveyed y values. The local R^2 value ranges from 0.0 to 1.0. Very low values indicate poor performance of the local regression model. The distribution of local R^2 values that the GWR predicts strongly and weakly is given in Figure 3.

Figure 3. GWR Local R^2 Distribution



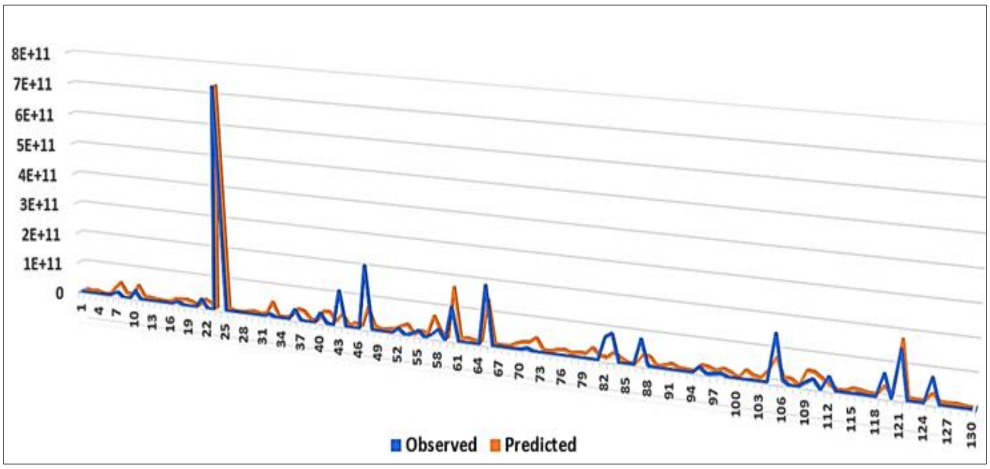
In Figure 3, the local R^2 value in 2019 varies between 0.86351 and 0.907501. Countries with high local R^2 value; Indonesia, Brunei, Malaysia, Australia, Vietnam, Cambodia, Singapore, South Korea, Japan, Thailand, Myanmar, China, Mongolia, Nepal, New Zealand and India. The countries with the lowest local R^2 (0.86351-0.873051) are the countries in the west of the African continent and the countries in the South American continent. It was determined that the confidence level of the model, the explanation and validity of the variables were strong in the south-east of the map and decreased from east to west except for the North American continent. In the spatial regression equation obtained by the GWR analysis, the independent variable values and the estimated values of the HTE of the countries were calculated. Thematic maps of the countries created according to these estimated values are divided into 5 classes with the Jenks Natural Breaks (JNB) method.

Figure 4. GWR Estimated HTE



According to Figure 4, in the classification of countries with very high estimated high technology exports, China was alone in the first group. The countries with a high estimated HTE are USA, Japan and South Korea. Countries in the middle class are Singapore, Germany, Israel, Sweden, Switzerland, Denmark, Austria, Belgium. Low class countries include Luxembourg, Finland, France, Czech Republic, Slovenia, Ireland, Malta, United Kingdom, Iceland, United Arab Emirates, Netherlands, Estonia, Norway, Vietnam, Malaysia, Seychelles, Canada, Australia, Slovakia, Poland, Italy, Lithuania, Hungary, Russia and Portugal. The remaining 93 countries are in the very low class of estimated HTE. The map created according to the estimated values of HTE in Figure 4 and the map created with the observed values of HTE in Figure 1 showed similarities. In addition, Graph 1 was created to compare this similarity.

Graph 1. Comparison of Observation and Estimate Values of HTE



When Graph 1 is examined, it is observed that the observed and estimated values of high technology exports are parallel to each other. This showed that the established GWR model performance was good and predicted very close to the real values.

6. CONCLUSION

Exports are an important determinant of a country's economic achievement. Countries that successfully market their products to the world and protect or raise the quality of life of their community can provide the indispensable resources for a healthy economy. Countries develop high technology industries in order to increase their economic level, gain more market share, make new markets or use resources more efficiently.

The purpose of this study is to evaluate the spatial relation between R&D expenditures, foreign direct investment net inflows, gross college enrolment, patent applications, trade openness, human development index and economic freedom index factors and High Technology Exports (HTE), taking into account the locational differences of the countries. These factors associated with HTE were chosen because they provided the best model fit as a result of exploratory regression. GWR analysis was applied to examine the spatial relationship between these selected factors and the HTE of 130 countries in 2019.

The local R^2 values calculated by GWR analysis, and the spatial explanation ratios of the selected independent variables to HTE vary between 0.86351 and 0.907501. It was observed that the local R^2 values were highest in the countries in the south-east of the map, and these countries were those around China. It was observed that the local R^2 value decreased from east to west, except for the North American continent. Even the lowest disclosure rate was found to be quite high with 86.351%.

The estimated values of HTE were calculated with the GWR model and it was determined that the observed values and the predicted values were close to each other. With Jenks Natural Breaks (JNB) classification technique, thematic maps of countries were created according to both values by dividing them into 5 classes as Very High, High, Medium, Low and Very Low.

When the explanatory variables in the model established in the study are examined, it is seen that R&D Expenditures, Foreign Direct Investment Net Inflows, Patent Applications, Trade Openness and Economic Freedom Index have a positive effect on HTE in all countries, while Gross Higher Schooling and Human Development Index (HDI) has a negative effect. The negative effect of Gross Schooling may be due to the fact that human capital, that is, educated workforce, is not at a level to produce high technology products. With the workforce capable of producing high technology products, qualified, high-quality and high-value-added products can be produced. The size of a country's economy is not enough to show that country's development. For example, although China ranks first in HTE, it ranks eighty-fifth in the Human Development Index (HDI). This may be the reason why HDI negatively affects HTE.

The GWR model established in this study showed that countries have a weak or strong spatial relationship with their neighboring countries in terms of HTE. It has been observed that this spatial relationship is strong in the countries neighbouring China, which ranks first in HTE, while the spatial relationship is weak in countries where HTE is low. As a result of this study, it has been observed that export relations with neighbouring countries are strengthened as countries increase their high value-added technological products. In this context, it has been seen that HTE is an important factor in international trade in order to increase the share and competitiveness of countries in international trade.

Countries need to develop some factor conditions in order to realize their high technology investments and exports. By changing the variables used in the study or adding other variables, the spatial relationships of the countries in HTE can be tested with the GWR analysis. One of the conditions associated with HTE is a highly trained labor force that will carry out R&D studies and transform these results into new products. Scientific disciplines and engineering should be the focus as they play an important role in driving a country's R&D. It is also important to support research collaborations in the form of R&D common initiative, licence agreements or private R&D agreements to support knowledge transfer from academia to industry. Governments should try to attract foreign direct investment and develop their investment policies in this direction, which will develop technology-dominated industries that can increase the economic productivity and growth of countries.

The variables that have been identified in the relevant literature as having a relationship with high-tech exports have been utilized in this study to investigate the spatial relationships of countries. Although numerous studies in the literature have been conducted on the factors influencing high-tech exports, no study has been encountered that examines the spatial relationships of countries in terms of high-tech exports. Therefore, it is anticipated that this study will also contribute to the literature in this scope.

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