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Relationship between economic growth and innovation in Vietnam's Southern Key Economic Region

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Abstract

This research uses the spatial regression method to investigate the relationship between economic growth and innovation activities in Vietnam's Southern Key Economic Region (SKER) in 2011-2022 to identify the bottlenecks and innovation factors that impact growth. The research results provide statistical evidence that there is a spatial interaction in the same direction in the GRDP growth rate between provinces and centrally-controlled municipalities in the SKER, but not at a high level. However, the biggest bottleneck to the entire SKER's economic growth is that the coordination mechanism is ineffective, the linkage mechanism between sectors and fields is either absent or loose, and the connection and assignment of tasks between localities is unclear. That is why the advantages and potentials of localities in the SKER cannot be promoted.

Keywords: spatial regression, economic growth, innovation.

JEL classification: O18, O3, R11, R5.

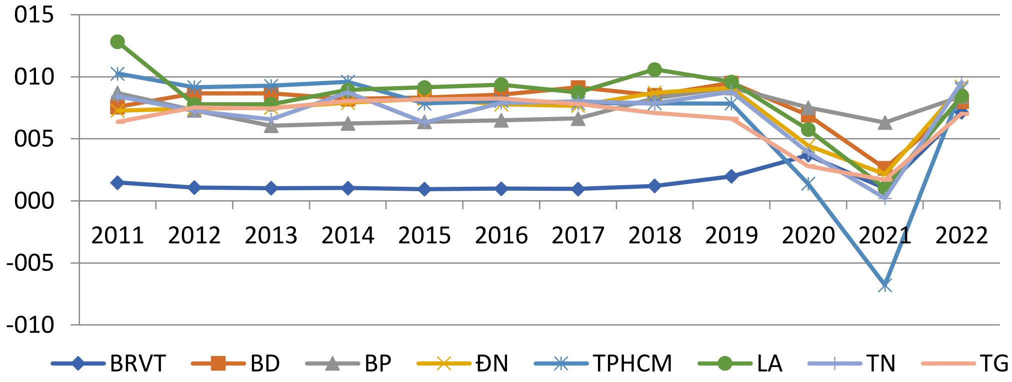
1. Introduction and literature review

The Southern Key Economic Region of Vietnam was established with a total area of nearly 30,603 square kilometers, making it the largest among the country's four key economic regions. The SKER comprises eight provinces and centrally-controlled municipalities, including Ho Chi Minh City, Dong Nai, Binh Duong, Ba Ria - Vung Tau, Tay Ninh, Binh Phuoc, Long An, and Tien Giang. Its strategic location along vital national transport corridors and its role as a trade gateway to regional and international markets make it a crucial driver of Vietnam's socioeconomic development.

From 2005 to 2010, Ho Chi Minh City and other localities in the SKER recognized the need to rapidly shift away from an extensive growth model that heavily relied on investment capital, low-cost labor, and natural resources. This model was no longer suitable and lacked sustainability. In the new phase, the urgent need for the localities in the SKER was to create new growth drivers and shift toward an intensive growth model to improve the quality of growth for each locality and the entire SKER.

An economic growth model based on science, technology, and innovation (abbreviated as innovation), underpinned by the theoretical foundation of endogenous growth, was the inevitable path chosen by Ho Chi Minh City and other localities in the SKER to address the challenges. Additionally, to promote the overall economic development of the SKER, localities have made efforts to establish and strengthen regional linkages, encouraging development in alignment with common goals. The aim is to collectively achieve quality growth, focusing on depth, optimizing the effective use of local resources based on science, technology, and innovation, and promoting the differences in comparative advantages of each locality.

FIGURE 1: **Economic growth of localities in Vietnam's Southern Key Economic Region for the period 2011-2022 (percent)**



Note: BRVT: Ba Ria - Vung Tau, BD: Binh Duong, BP: Binh Phuoc, DN: Dong Nai, TPHCM: Ho Chi Minh City, LA: Long An, TN: Tay Ninh, TG: Tien Giang

Source: The author created from data of the General Statistics Office of Vietnam.

Economic linkages between localities are often reflected through the economic spillover effects, also known as economic diffusion effects across localities. The spillover capability among neighboring localities makes the economic development or conditions in these localities similar, also referred to as correlations. These similarities provide an essential basis for applying spatial statistical methods on spatial correlation to test the diffusion effects of economic linkages between localities. Nguyen and Nguyen (2019) used a spatial econometric model to study exports across 63 provinces and municipalities in Vietnam from 2013 to 2017, identifying correlations in export activities between neighboring localities. Nguyen and Tran (2019) examined the degree of economic linkages between localities using a spatial regression method with data collected from 2010 to 2017. Their findings indicated that capital and labor factors not only positively impacted the economic growth scale of a locality but also positively influenced the economic scale of neighboring localities. Ha *et al*. (2020) used data on GRDP, capital scale, labor force, and trade openness from 63 provinces and municipalities in Vietnam from 2010 to 2017 to test income convergence among provinces using spatial regression. Their findings provided statistically reliable evidence of absolute and conditional convergence in local economic efficiency. Pham (2021) used the panel data regression method for the period 2000-2017 to analyze the impact of factors on economic growth quality in the SKER. The research revealed that investment capital, labor force, and export value positively affected the economic growth scale of the SKER.

When studying spatial dependence among localities, estimation results of econometric models using the traditional ordinary least squares (OLS) method are often biased and inefficient. According to Anselin (2003) and Elhorst (2014), spatial econometric models with panel data are now widely recognized as more accurate estimation methods because they explain spatial and temporal characteristics for different research when spatial dependence exists among observations.

For the above reasons, this research uses econometric models with spatial regression methods and panel data from eight provinces and municipalities in the SKER for the period 2011-2022. The objective is to analyze the relationship between economic growth and science, technology, and innovation-related activities to identify bottlenecks potentially hindering the SKER's economic growth.

2. Research method

2.1 Theoretical basis of spatial regression

2.1.1 Moran's I coefficient - Spatial weight matrix

To measure spatial correlation among research objects, economists commonly use the Moran's I coefficient, which is determined by the following formula:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^{n}(X_i - \bar{X})^2}$$

Of which: X_i: value of the research variable in the i^{th} locality; $\bar{X}$: mean of variable X; w_{ij}: spatial weight between the i^{th} and j^{th} localities; n: number of observations.

Moran's I coefficient is in the range [-1;1]. A positive coefficient indicates that neighboring localities will have a positive spatial correlation. On the contrary, a negative coefficient indicates that localities have an inverse spatial correlation. Interpreting positive or negative correlations heavily depends on constructing the spatial weight matrix during testing.

The statistical significance test of Moran's I coefficient is performed based on the hypothesis H_0, which states that no spatial correlation exists among the research variables across localities.

The spatial weight matrix (symbol W) plays an important role in spatial econometric analysis and integrates spatial dependence into the research model. The spatial weight matrix is a square matrix ($n \times n$; $n \in N$) that satisfies the following two conditions:

Firstly, all the component values W_{ij} (weights) are non-negative ($w_{ij} > 0$). The values of the weights w_{ij} represent the level of spatial interaction between locality j and locality i.

Secondly, all the weights on the main diagonal of the matrix are zero ($w_{ii} = 0$). This implies that a locality does not interact with itself.

Since there is always reciprocal interaction between two localities i and j, the characteristic of the spatial matrix is that the weights are symmetrical across the main diagonal ($w_{ij} = w_{ji}$).

$$W = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{bmatrix}$$

Anselin (1988) proposed that, in the experiment, the spatial weight matrix be constructed in the form of row normalization, meaning that the sum of the weights on each row of the matrix is equal to 1 and the value of each element is calculated according to the following formula:

$$w_{ij}^{s} = \frac{w_{ij}}{\sum_{j} w_{ij}}; \qquad \sum_{j=1}^{n} w_{ij}^{s} = 1$$

Smith (2017) indicated that there are several methods for constructing the weights of a spatial weight matrix, which can be categorized into three main groups based on: (i) the distance between localities, (ii) the contiguity of localities, and (iii) the normalization of weight values.

In this research, the author uses a spatial contiguity matrix. Coughlin and Segev (2000) said that if locality i shares a boundary with locality j ($i \neq j$), they are considered to have spatial correlation. The elements of the spatial weight matrix are determined as follows:

$$w_{ij} = \begin{cases} 1 & \text{i and j share a boundary.} \\ 0 & \text{i and j do not share a boundary.} \end{cases}$$

2.1.2. Econometric models with panel data

The spatial regression model, first introduced by Cliff and Ord (1981) and later perfected by Anselin (1988), is known as the spatial autoregressive model (SAR). Studies by LeSage (1999), Elhorst (2014) and other experts have highlighted various issues related to testing and estimation in spatial econometric models with panel data, including endogenous interaction effects, exogenous interaction effects, error interaction effects, direct spatial spillover effects, indirect spatial spillover effects, random effects model (REM), and fixed effects model (FEM). In recent years, a variety of models have been used for estimation with spatial panel data, such as Spatial Lag Model (SLM), Spatial Error Model (SEM), and Spatial Durbin Model (SDM). According to Vega and Elhorst (2015), these models, among others, are considered variants of the General Nesting Spatial Model (GNS) (see Appendix). Based on the degree of spatial correlation, regression models can be classified as follows: (i) SAR, SLX, and SEM have one spatial correlation parameter; (ii) SAC, SDM, and SDEM have two spatial correlation parameters; and (iii) GNS has three spatial correlation parameters.

The GNS model is typically expressed as follows:

$$Y = \rho WY + \alpha t_N + X\beta + WX\theta + u \quad (1)$$

$$u = \lambda Wu + \varepsilon$$

Of which: Y: (Nx1) vector of the dependent variable; N: the number of spatial locations researched; X: (NxK) matrix of explanatory variables; K: the number of explanatory variables; W: (NxN) spatial weight matrix; αt_N: intercept coefficient of the model; ρ: spatial autocorrelation parameter; WY: spatial lag of the dependent variable; ρWY: endogenous interaction effect; θ: spatial exogenous interaction parameter; WX: spatial explanatory variable; $WX\theta$: exogenous interaction effect; β: (Kx1) matrix of explanatory variable parameters; λ: spatial error correlation parameter; u: spatially and temporally correlated errors; λWu: error interaction effect; ε: normally distributed time-specific error $(0,\sigma^2)$.

2.2. Testing models

To test for the spatial correlation in economic growth among localities in the SKER, the spatial contiguity weight matrix (presented in the theoretical basis section) is used to calculate and test the statistical significance of the Moran’s I coefficient. Additionally, to expand the research, an open spatial contiguity weight matrix is also used. The open spatial contiguity weight matrix is a square matrix (8x8), except for the elements on the main diagonal w_{ii} equal to 0, the other elements w_j are all equal to 1 ($i \neq j$). The reason why the weight values in the open spatial contiguity weight matrix are all equal to 1 (except for the values on the main diagonal) is because in the era of Industry 4.0, localities not only interact geographically but also through digital networks, enabling mutual impacts across all localities.

If the Moran’s I coefficient statistical test indicates spatial correlation, regression models are tested to estimate the coefficients and analyze the spatial correlation of economic growth based on innovation among localities in the SKER. In order to expand the research and consider and evaluate from many perspectives, the author selects three groups of spatial regression models for analysis based on the level of spatial correlation from simple (models with only one correlation parameter) to complex (models with three correlation parameters). Specifically, as follows:

The first group, models with one spatial correlation parameter: Select two spatial autoregressive models (SAR) and spatial error models (SEM).

SAR: $Y = \rho WY + \alpha t_N + X\beta + \varepsilon$ (spatial autocorrelation parameter: ρ)

SEM: $Y = \alpha t_N + X\beta + u$ (spatial error correlation parameter: λ)

$u = \lambda Wu + \varepsilon$

The following steps are undertaken to choose the most appropriate model for explanation:

Step 1: Each SAR and SEM model has two forms: Random Effects Model (REM) and Fixed Effects Model (FEM); the author will base on the Hausman test results to determine whether REM or FEM is more appropriate.

Step 2: The Bayesian Information Criterion (BIC) is used to choose between SAR and SEM models.

The second group, models with two spatial correlation parameters: Choose spatial autoregressive combined models (SAC) and Spatial Durbin Model (SDM).

SAC: $Y = \rho WY + \alpha t_N + X\beta + u$

(spatial autocorrelation parameter: ρ

$u = \lambda Wu + \varepsilon$

and spatial error correlation parameter: λ)

SDM: $Y = \rho WY + \alpha t_N + X\beta + WX\theta + \varepsilon$

(spatial autocorrelation parameter: ρ and spatial correlation independent variables parameters: θ)

The steps for selecting the appropriate model for explanation are similar to those for selecting models with one spatial correlation parameter, using the Hausman test and BIC.

The third group, GNS model with three spatial correlation parameters: Choose two GNS models using a spatial contiguity weight matrix (GNS-W) and another using both the spatial contiguity weight matrix and the open spatial contiguity weight matrix (GNS-W, Wi). Theoretically, a spatial regression model with three spatial correlation coefficients (ρ; λ; θ) can correspond to three different spatial weight matrices. This is also consistent with reality because the spatial correlation mechanisms of the dependent variable, explanatory variables, and errors may be entirely similar, partially similar, or completely different. In this section, as with previous model groups, Hausman test and BIC are used as criteria for selecting the most appropriate model.

2.3. Research data

For all spatial regression models tested and estimated, the dependent variable Y vector (8x1) is used, which is the annual GRDP growth data of eight provinces and municipalities in the SKER for 2011-2022. The GRDP data of the provinces and municipalities collected by the author is secondary data from the General Statistics Office of Vietnam. The explanatory variable X is an (8x2) matrix with two components of the explanatory variable: (x1) the growth rate of total factor productivity (TFP) and (x2) the growth rate of the science, technology, and innovation index.

TFP reflects advancements in science, technique, technology, education, and training. TFP growth is associated with the application of technical advances, technological innovation, improved management methods, and workforce skill and qualification improvement. The author collects TFP data and TFP growth rate calculations from sources and implements them according to the guidance methodology provided by the General Statistics Office of Vietnam.

Currently, the GII (Global Innovation Index) is widely recognized as a tool for measuring innovation that is superior, more comprehensive, and more accurate than traditional measurement methods. The GII is evaluated at the national level by the World Intellectual Property Organization (WIPO). However, the statistical data on innovation at the local level in Vietnam was unavailable until the end of 2023. In early 2024, Vietnam officially introduced the Provincial Innovation Index (PII), providing statistical data for 2023. Since this research uses data from 2011 to 2022, the author does not use the PII data set but inherits the research method of the GII and PII data sets. On that basis, the author proposes to use the data on the number of registered IP assets of provinces and municipalities nationwide in four areas: patents (inventions), utility solutions (helpful technical solutions), trademarks, and industrial design improvements. These statistics are compiled and published quarterly and annually by the Intellectual Property Office of Vietnam, under the Ministry of Science and Technology, on their website https://ipvietnam.gov.vn/.

The total number of patents, utility solutions, trademarks, and industrial designs in a year is denoted as N_{STI}. To create a research variable related to innovation activities and local economic growth, the author proposes calculating the STI (Science Technology and Innovation) index as the ratio of N_{STI} to the locality's economic growth rate (G) in the research year (i.e., $STI = N_{STI}/G$). The practical significance of this ratio is that the number of N_{STI} applied corresponds to a 1% increase in GRDP.

The growth rate of STI, denoted as I, is the x_2 variable of the spatial regression models.

$I = (STI_{t+1} - STI_t)/STI_t$

Through algebraic transformations, the following observations can be made: if I is negative, the growth rate of N_{STI} is less than the GRDP growth rate; if I is non-negative, the growth rate of N_{STI} is greater than or equal to the GRDP growth rate.

3. Research results and discussion

3.1. Descriptive statistics - Spatial correlation test

Table 1 presents the descriptive statistics for the GRDP growth rate, TFP growth rate, and STI growth rate of eight provinces and municipalities in Vietnam's Southern Key Economic Zone for the period 2011-2022.

TABLE 1: **Descriptive statistics**

	GRDP growth rate (%)	**TFP growth rate (%)**	**STI growth rate (%)**
Mean	6.62	1.84	37.64
Sample error	0.32	0.24	17.58
Median	7.78	2.17	5.98
Mode	1.02		
Standard deviation	3.14	2.33	172.26
Sample variance	9.85	5.45	29.673.48
Range	19.60	16.36	1.643.16
Minimum	-6.78	-6.86	-175.53
Maximum	12.82	9.50	1.467.63
Number of observations	96	96	96
95% confidence interval	0.6279	0.4694	34.4585

Source: Author's calculation.

Table 2 presents the results of testing the spatial correlation according to Moran's I coefficient of the GRDP growth rate, TFP growth rate, and STI growth rate of eight provinces and municipalities in the SKER for 2011-2022.

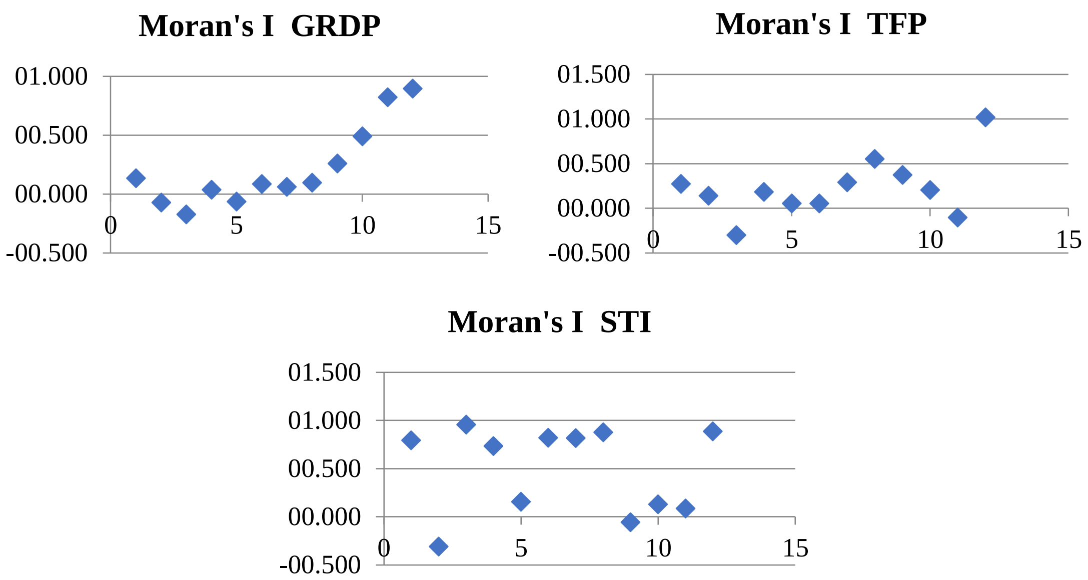
TABLE 2: **Moran's I coefficient test, with spatial contiguity weight matrix**

Year	GRDP growth rate (%)	TFP growth rate (%)	STI growth rate (%)
2011	0.1345	0.2727	0.7935
2012	-0.0702	0.1416	-0.3079
2013	-0.1733	-0.3015	0.9583
2014	0.0385	0.1825	0.7351
2015	-0.0630	0.0560	0.1572
2016	0.0860	0.0533	0.8223
2017	0.0619	0.2925	0.8198
2018	0.0969	0.5530	0.8779
2019	0.2606	0.3749	-0.0573
2020	0.4904	0.2045	0.1299
2021	0.8238	-0.1019	0.0885
2022	0.8960	1.0175	0.8880
Mean	0.2152	0.2288	0.4921
Variance	0.1194	0.1105	0.2034
Standard deviation	0.3455	0.3325	0.4510
t_0	1.9692	2.1759	3.4505
p-value	0.0772	0.0546	0.0062

Source: Author's calculation.

The results show that Moran's I coefficients fluctuate between negative and positive values across different years and are statistically significant at 1% or 10%. This finding indicates the presence of spatial correlation (either in the same or opposite direction) regarding the GRDP, TFP, and STI growth rates between provinces and municipalities in the SKER for 2011-2022. Figure 2 shows the scatter diagram of Moran's I coefficient of GRDP, TFP, and STI growth rates among provinces and municipalities in the SKER for 2011-2022.

FIGURE 2: **Scatter diagram of Morans' I coefficient by year**



Source: Data collected, calculated and presented by the author.

TABLE 3: **Comparison and selection of regression models with one spatial correlation parameter**

Coefficient/Spatial parameter/Model test criteria	**SAR**		**SEM**	
	REM	**FEM**	**REM**	**FEM**
Coefficient β_1(TFP)	0.2392** [2.47]	0.2020** [2.10]	0.3339*** [3.27]	0.2772*** [2.76]
Coefficient β_2(I)	-0.0366*** [-2.96]	-0.0012*** [-2.68]	-0.0017 [-1.50]	-0.0015 [-1.31]
Intercept coefficient (αt_N)	2.8096*** [3.76]		5.9285*** [3.76]	
Spatial autocorrelation parameter (ρ)	0.1561*** [7.26]	0.1664*** [7.76]		
Spatial error correlation parameter (λ)			0.1871*** [9.86]	0.1884*** [9.90]
Hausman test	χ^2 = 3.30 Prob> χ^2 = 0.1916		χ^2 = 3.47 Prob> χ^2 = 0.1762	
Log likelihood	-203.9277	-178.6000	-204.6311	-179.6414
AIC	419.8555	365.2000	421.2623	367.2829
BIC	435.2416	375.4574	436.6484	377.5403

Note: **, *** represent significance levels at 5%, and 1% respectively; values in square brackets are the Z-scores in statistics.

Source: Author's calculation.

3.2. Testing of spatial regression models

In this section, the author will test three groups of spatial regression models: one-parameter, two-parameter, and three-parameter models. Within each group, the author selects the most appropriate model based on the criteria (Hausman, BIC) to analyze the spatial effects among the provinces and municipalities in the SKER. The results of comparing and selecting representative models for the three groups are presented in detail in Table 3, Table 4 and Table 5. Finally, the estimated results for the three representative models of the groups are summarized in Table 6.

3.2.1. Spatial regression model with one spatial correlation parameter

For the regression models with one spatial correlation parameter, the author selects the following two models for testing: the Spatial Autoregressive Model (SAR) and the Spatial Error Model (SEM). With the two models above combined with two forms of random effects (REM) and fixed effects (FEM), four models are tested. Table 3 presents the comparison results, showing that the Spatial Autoregressive Model with Random Effects (SAR-REM) is the most suitable for explaining spatial correlation regarding economic growth based on innovation in the provinces and municipalities of the SKER.

3.2.2. Spatial regression model with two spatial correlation parameters

Similar to Section 3.2.1, the author selects the Spatial Autoregressive Model (SAC) and the Spatial Durbin Model (SDM) for testing for the two-parameter regression models. Table 4 presents the comparison results, showing that the Spatial Durbin Model with Fixed Effects (SDM-FEM) is the most suitable for explaining spatial correlation regarding economic growth based on innovation in the provinces and municipalities of the SKER.

TABLE 4: **Comparison and selection of regression models with two spatial correlation parameters**

Coefficient/Spatial parameter/Model test criteria	**SAC**		**SDM**	
	REM	**FEM**	**REM**	**FEM**
Coefficient β_1(TFP)	0.1046 [0.98]	0.0626 [0.69]	0.2382*** [2.64]	0.1929** [2.16]
Coefficient β_2 (I)	-0.0044*** [-3.63]	-0.0041*** [-3.55]	-0.0045*** [-4.05]	-0.0047*** [-4.03]
Intercept coefficient (αt_N)	2.4035*** [3.28]		5.8764*** [5.84]	
Spatial autocorrelation parameter (ρ)	0.1860*** [9.22]	0.1965*** [11.36]	0.0816*** [2.65]	0.0655* [1.86]
Spatial error correlation parameter (λ)	-0.1366* [-1.70]	-0.1623** [-2.52]		

Spatial correlation parameter for the independent variable TFP(θ_{TFP})			-0.1505***	-0.1533***
			[-3.31]	[-3.35]
Spatial correlation parameter for the independent variable I (θ_I)			-0.0026***	-0.0028***
			[-4.42]	[-4.53]
Hausman test	$\chi^2 = 1.53$ Prob> $\chi^2 = 0.4643$		$\chi^2 = 9.31$ Prob> $\chi^2 = 0.0095$	
Log likelihood	-203.2702	-176.8284	-186.9387	-179.6414
AIC	420.5404	363.6568	389.8775	367.2829
BIC	438.4908	376.4786	410.3923	377.5403

Note: *, **, *** represent significance levels at 10%, 5%, and 1% respectively; values in square brackets are the Z-scores in statistics.

Source: Author's calculation.

3.2.3. Spatial regression model with three spatial correlation parameters

For the regression models with three spatial correlation parameters, the author selects the general spatial model using the spatial contiguity matrix (W) and the general spatial model using both the contiguity matrix and the open contiguity matrix (W&Wi). The difference between the two models is that in the GNS1 model, all three spatial weight matrices are the contiguity matrix W, while in the GNS2 model, the spatial matrix for the independent variables (the matrix creating the exogenous interaction effects) is the open contiguity matrix Wi, the remaining two matrices are contiguity matrices W.

GNS1 (W): $Y = \rho WY + \alpha t_N + X\beta + WX\theta + u$

$u = \lambda Wu + \varepsilon$

GNS2 (W&Wi): $Y = \rho WY + \alpha t_N + X\beta + WiX\theta + u$

$u = \lambda Wu + \varepsilon$

Similar to Section 3.2.2, Table 5 presents the comparison results, showing that the general spatial model - the contiguity matrix with random effects (GNS1-REM) is the most suitable for explaining spatial correlation regarding economic growth based on innovation in the provinces and municipalities of the SKER.

TABLE 5: **Comparison and selection of spatial regression models with three spatial correlation parameters**

Coefficient/Spatial parameter/Model test criteria	**SAC**		**SDM**	
	REM	**FEM**	**REM**	**FEM**
Coefficient β_1 (TFP)	0.2315**	0.1899**	0.0831	0.0273
	[2.52]	[2.10]	[0.79]	[0.27]
Coefficient β_2 (I)	-0.0042***	-0.0044***	-0.0035***	-0.0032**
	[-3.53]	[-3.39]	[-2.75]	[-2.47]
Intercept coefficient (αt_N)	5.5555***		4.9544***	
	[5.32]		[4.49]	
Spatial autocorrelation parameter (ρ)	0.0937***	0.0775*	0.1095***	0.1199***
	[2.86]	[1.90]	[3.24]	[3.23]

Spatial error correlation parameter (λ)	-0.0422 [-0.76]	-0.0302 [-0.51]	-0.1006 [-1.64]	-0.1187** [-1.96]
Spatial correlation parameter for the independent variable TFP (θ_{TFP})	-0.1446*** [-3.32]	-0.1468*** [-3.21]	-0.0345 [-1.45]	-0.0255 [-1.13]
Spatial correlation parameter for the independent variable I (θ_I)	-0.0025*** [-4.32]	-0.0027*** [-4.25]	-0.0014*** [-3.48]	- 0.0013*** [-3.11]
Hausman test	$\chi^2 = 5.37$ Prob>$\chi^2 = 0.0683$		$\chi^2 = 4.04$ Prob>$\chi^2 = 0.1328$	
Log likelihood	-186.6474	-161.2411	-195.0775	-169.8209
AIC	391.2949	336.4822	408.1551	353.6419
BIC	414.3740	354.4326	431.2342	371.5923

Note: *, **, *** represent significance levels at 10%, 5%, and 1% respectively; values in square brackets are the Z-scores in statistics.

Source: Author's calculation.

3.2.4. Comparison and evaluation of estimation results

Table 6 summarizes of the estimation results for the SAR-REM, SDM-FEM, and GNS1-REM spatial regression models. The estimated values of all models are statistically significant (with 1%, 5%, and 10% confidence levels), except for the spatial error correlation parameter (λ) of the GNS1-REM model, which provides for testing the spatial correlation of localities in the SKER.

TABLE 6: **Summary of the estimated results of selected spatial regression models**

Variable/Spatial parameter	**SAR-REM**	**SDM-FEM**	**GNS1-REM**	**Spatial effect**
Coefficient β_1(TFP)	0.2392**	0.1929**	0.2315**	Direct Spillover Effect TFP → GRDP
Coefficient β_2 (I)	-0.0366***	-0.0047***	-0.0042***	Direct Spillover Effect I → GRDP
Intercept coefficient (αt_N)	2.8096***		5.5555***	
Spatial autocorrelation parameter (ρ)	0.1561***	0.0655*	0.0937***	Endogenous Interaction Effect GRDP
Spatial error correlation parameter (λ)			-0.0422	Error Interaction Effect
Spatial correlation parameter for the independent variable TFP (θ_{TFP})		-0.1533***	-0.1446***	Exogenous Interaction Effect GRDP
Spatial correlation parameter for the independent variable I (θ_I)		-0.0028***	-0.0025***	Exogenous Interaction Effect GRDP

Note: *, **, *** represent significance levels at 10%, 5%, and 1% respectively; values in square brackets are the Z-scores in statistics.

Source: Author's calculation.

In general, most of the estimated values for the coefficients (β_1, β_2) and parameters (ρ, θTFP, θI) in all three models are similar in terms of both the magnitude and direction of impact (positive or negative).

The coefficient β1 for the explanatory variable (TFP) in all three models is 0.2392, 0.1929, and 0.2315, respectively, indicating that TFP has a direct and positive spillover effect on the GRDP growth rate of each locality in the SKER. However, the spatial correlation parameter (θTFP) has a negative value, suggesting that the TFP growth rates of neighboring provinces and municipalities indirectly reduce the GRDP growth rate of localities within the SKER. This influence is an exogenous spatial interaction effect. Specifically, when the TFP growth rate of neighboring provinces and municipalities increases by one unit, the GRDP growth rate of the locality decreases by 0.1533 (in the two-parameter model) or 0.1446 units (in the three-parameter model). Considering the total effect (both direct and indirect) of the TFP factor, when it increases by one unit, the GRDP growth rate of the locality increases by 0.0396 units (in the two-parameter model) or 0.0869 units (in the three-parameter model). The negative indirect effect of the exogenous interaction effect of TFP on GRDP could be explained by the ineffective coordination mechanism between localities in the SKER or a lack of clear or existing links.

The coefficient β2 for the explanatory variable (I) is negative, proving that the STI and GRDP growth rates have an inverse relationship. The parameter (θI) is also negative, indicating that the exogenous interaction effect of the STI growth rate in neighboring provinces and municipalities also negatively impacts the GRDP growth rate of localities in the SKER. Thus, in general, the STI factor's total effect (both direct and indirect) is negative on the GRDP growth rate of localities. The estimated values for the impact of the STI factor are relatively small, suggesting that the GRDP growth rates of provinces and municipalities in the SKER do not change significantly in response to changes in the number of STI registrations and certificates (patents, utility solutions, trademarks, and industrial designs).

For the spatial autocorrelation parameter (ρ), the estimated values in all three models are 0.1561, 0.0655, and 0.0937, respectively, providing statistically reliable evidence that the past GRDP growth rate of neighboring provinces and municipalities positively affects the current GRDP growth rate of localities in the SKER. The spatial correlation of the GRDP growth rate between the provinces and municipalities in the SKER creates an endogenous effect with a positive effect.

The spatial error correlation parameter λ has an estimated value of -0.0422, which is not statistically significant and is only for reference. Therefore, there is no evidence of the influence of the error of neighboring provinces and municipalities on the error of localities within the SKER.

4. Conclusion and policy recommendations

The testing of three groups of spatial regression models shows that most of the estimates are statistically significant with high reliability (5%, 1%) and exhibit great consistency in analyzing and evaluating economic growth based on innovation of the SKER during the period 2011-2022. From the research results, the following are the conclusions and policy recommendations:

Firstly, the TFP growth rate factor has a direct positive effect on the GRDP growth rate of each locality within the SKER. However, the indirect spillover effect of the TFP growth rate (the exogenous interaction effect of TFP) of neighboring provinces and municipalities negatively impacts the GRDP growth rate of a locality. Although the total impact of the TFP growth rate factor on the GRDP growth rate is positive, the overall impact of the TFP growth rate is quite small. This research provides statistical evidence that the negative impact of TFP's exogenous interaction effect is the bottleneck for economic growth in the SKER. This indicates that the SKER's coordination mechanism is ineffective, with weak or non-existent linkages between industries and fields, as well as unclear or insufficiently defined roles and responsibilities among localities in the SKER. Consequently, the region has not fully exploited the advantages and potential of its localities. In the future, to develop the Southern Key Economic Region in particular and the key economic zones of Vietnam in general, the Government needs to institutionalize the linkage between provinces and municipalities in the SKER into a unified system. This system must be free from subjective or imposed constraints and must establish a strong, effective coordination mechanism that transcends administrative boundaries.

Secondly, the STI growth rate factor (abbreviated as "I") exerts both direct and indirect negative effects on the GRDP growth rate of localities in the SKER. This suggests that the NSTI growth rate (patents, utility solutions, trademarks, and industrial designs) is either slower than the GRDP growth rate or vice versa. All estimated impacts (direct, indirect, and total) of the factor I are very small, indicating that the GRDP growth rates of the provinces and municipalities in the SKER are minimally influenced by changes in STI growth rate. This is evidence that, in recent times, innovation activities have increased in the number of certificates and applications (patents, utility solutions, trademarks, and industrial designs) but have not really entered the socio-economic life of the SKER in particular and all provinces and municipalities of Vietnam.

In the future, the Government needs to implement policies that quickly transform "innovation" into "economic value" rather than merely increasing innovation and allowing it to spread naturally. This requires the Government to build and enhance a national innovation system urgently.

Thirdly, the past GRDP growth rates of neighboring provinces and municipalities positively affect the current GRDP growth rate of localities in the SKER. The spatial autocorrelation of the GRDP growth rate among provinces and municipalities in the SKER creates an endogenous interaction effect in the same direction but at a low level. This result further confirms that the most significant obstacle to the Southern Key Economic Region's development is the ineffective and insubstantial linkage and cooperation in economic development. Economic growth between Ho Chi Minh City - the region's economic leader - and other localities remains fragmented and uncoordinated. It lacks a specific division of labor and action plans between localities to develop industries with the advantages of each locality.

Over the years, localities in the SKER have independently developed their economic sectors, focusing only on maintaining annual growth rates. In some cases, this independent growth has led to competition among localities, eliminating the entire region's growth.

Thus, to ensure sustained economic growth in the future, beyond institutionalizing regional linkages, localities within the SKER must strengthen collaboration across all sectors, particularly in innovation. Additionally, the SKER should prioritize developing and improving transportation infrastructure to enhance connectivity within national and international transportation networks./.

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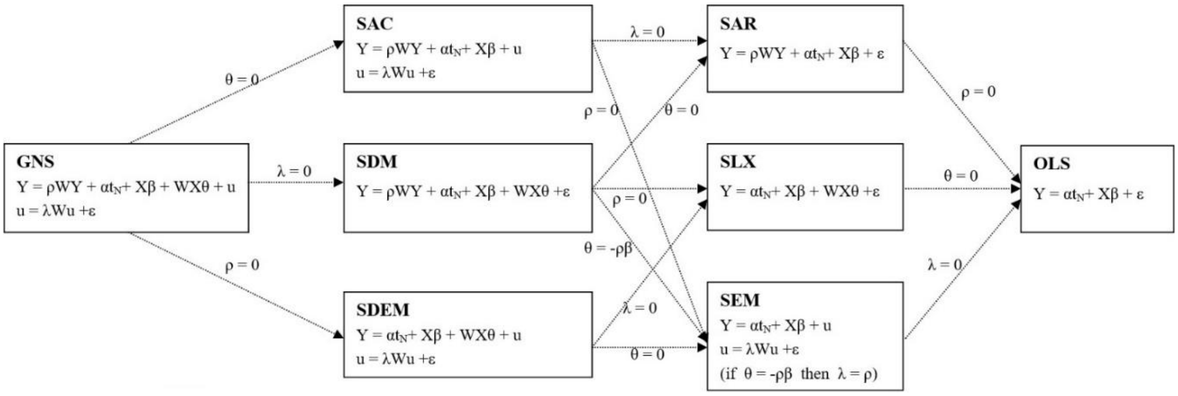
APPENDIX: **Relationships between spatial econometric models**



Note: GNS: General Nesting Spatial Model; SAC: Spatial Autoregressive Model; SDM: Spatial Durbin Model; SDEM: Spatial Durbin Error Model; SAR: Spatial Autoregressive Model; SLX: Spatial Autocorrelation Model of Independent Variables; SEM: Spatial Error Regression Model; OLS: Ordinary Least Squares Regression Model.

Source: Elhrost (2014).

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