IMPACT OF PUBLIC INVESTMENT GOVERNANCE ON PROVINCES' ECONOMICS GROWTH: A SPATIAL APPROACH

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Abstract

The objective of this study is to evaluate the impact of public investment on the economic growth of the province in Vietnam, with a focus on a spatial perspective to uncover its effects. Applying the quasi-maximum likelihood (quasi-ML) estimation method developed by Belotti et al. (2017) to balanced panel data and conducting various tests, we identified the spatial Durbin model (SDM) as the most appropriate spatial model for the studied data. The importance of public investment in local economic growth is highlighted by an empirical analysis of 63 Vietnamese provinces from 2010 to 2020. Notably, taking spatial interactions into account, the finding reveals the existence of spillover effects of economic growth and public investment, demonstrating the impact of economic growth and public investment from one province on the economic growth of adjacent provinces. We incorporate the impact of foreign direct investment (FDI) in the analysis to highlight the role of public investment in economic growth in the long run. While FDI also has positive impacts on regional growth and has direct effects on neighboring provinces' growth, it also has an adverse impact in terms of (indirect) spillover effects.

Keywords: Public Investment, Economic Growth, Spatial Econometric Model

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1. INTRODUCTION

The impact of public investment on regional economic growth has been widely discussed in the literature; however, the classical empirical results are not uniform. Public investment is considered a driving force for economic growth and a source of economic development (Solow, 1956; Barro, 1990) from one perspective. Aschauer (1989a, 1989b) argued that public infrastructure is essential in explaining the differences in production levels and territorial development by territory. This viewpoint has received support from numerous studies (Munnell, 1990a, 1990b; Berndt & Hansson, 1992; Nadiri & Mamuneas, 1994). Conversely, the alternative perspective questions the impact of public investment on output and indicates that the impact of public infrastructure investment is negative or insignificant (Sturm & de Haan, 1995; Pereira & Roca-Sagalés, 2003). The ongoing debate between the two viewpoints might imply that factors like data sources, methodology, or geographical features, can cause different findings among studies.

In recent years, spatial studies on the impact of public investment on economic growth have emerged, leading to a growing consensus within the field. Generally, studies incorporating the spatial consideration tend to emphasize that public investment plays a role in the geographical distribution of economic activities and fosters spillover effects between different regions (Kamps, 2005; Välilä et al., 2005; Rodríguez-Pose & Crescenzi, 2008; Kemmerling & Stephan, 2008; Ottaviano, 2008). Välilä et al. (2005) and the European Commission (EC, 2007) highlight the indispensable role of public investment in the European Union (EU) on output across the EU region. In the same vein, an investigation of the impact of investments by the European Restructuring Fund reveals a positive relationship in terms of linkages between countries/regions with different levels of impact (Cappelen et al., 2003; Rodríguez-Pose & Fratesi, 2004; Puigcerver-Peñalver, 2007). The European Central Bank (ECB, 2016) also demonstrates that public investment can positively affect economic growth through increasing aggregate demand and efficient public investment can increase the public capital stock, thereby promoting the economy's production capacity.

As Anderson and van Wincoop (2003) argued, localities within the same country are often closely linked due to their adherence to crucial policies of the central government, and neighboring localities are more advantageous when carrying out commercial transactions with geographically distant provinces. Dall'erba and Le Gallo (2008) show that with funds being allocated at the regional level, it seems more relevant to focus on their impact on the same level of spatial desegregation.

In Vietnam, several studies have also shown the positive impact of public investment on economic growth (Pham, 2023; Nguyen & Nguyen, 2021; Bon, 2019; Nguyen & Trinh, 2018). However, these studies consider the impact of public investment on economic growth without considering the spatial spillover effect of public investment for growth. So, different from previous studies in Vietnam on the impact of public investment on economic growth, this paper deploys the spatial approach, using province-level data in the period 2010–2020. Specifically, we analyze the spillover effects of public investment on economic growth in various localities using spatial econometric models. This approach addresses the question:

RQ: Beyond its impact on economic growth in the locality where the investment is made, does public investment also affect the economic growth of other localities?

The rest of the paper is organized as follows. An introduction, which details the research and summarizes the theoretical and empirical previous studies about the influence of public investment on economic growth to identify the research gaps in Vietnam is found in Section 1. In addition to the introduction, a literature review and an overview of the economic growth and public investment in Vietnam's provinces are described in Section 2. The methodology is introduced in Section 3. The estimation results and discussion are presented in Section 4. The conclusion and policy implications of Section 5 are intended to promote economic growth in Vietnam's provinces.

2. LITERATURE REVIEW

2.1. Spatial impact of public investment on economic growth

Due to the need to account for the location and spatial interaction in social and economic studies, spatial econometrics have gained increasing attention. Key contributors include Anselin (1988), who pioneered methods for analyzing spatial data, and Baltagi and Li (2006), who pointed out that accounting for spatial correlation can improve forecasting results. Other notable figures, such as LeSage and Pace (2009), Elhorst (2014), Kelejian and Prucha (1999), and Florax and Folmer (1992), have further advanced methods and an understanding of spatial effects. Following, empirical applications of spatial econometric models in analyzing the spillover effects of public investment have been robustly developed over the past two decades. These studies use spatial econometric models to gain a better understanding of how public investment not only directly affects the invested region but also spills over to neighboring areas. Cohen and Morrison Paul (2004) and Cohen (2010) highlight the significant impact of public infrastructure investment on production costs and economic growth through spatial effects. Konno et al. (2021) conducted an empirical analysis of the productivity impacts of road infrastructure, incorporating spatial spillover effects using a multi-country database and spatial econometric models. The spatial Durbin model's (SDM) estimated results indicate that road infrastructure has a significant negative direct impact, but it has a significant positive spatial spillover impact, and the overall impact is positive but not significant. Wang et al. (2022) and Wang and Liu (2023) employ spatial econometric models to analyze the spatial spillover effects of energy, transportation, and information infrastructure on urban green and smart development in China, revealing diverse impacts across regions and sectors.

Further studies by Crescenzi and Rodríguez-Pose (2012), Rodríguez-Pose et al. (2012), Zeng et al. (2019), and others have provided valuable insights into the spatial dynamics of public investment across different contexts. Crescenzi and Rodríguez-Pose (2012) examined the impact of public investment and human capital on economic growth in European regions from 1990 to 2004. Their findings indicate that public investment in education and training positively affects regional economic growth, although this effect varies depending on the economic development level of the regions. The study by Rodríguez-Pose et al. (2012) provided insightful perspectives on the role of public investment in regional economic development in Greece, with a policy implication that public investment policies can be designed to not only support the directly invested areas but also bring benefits to neighboring areas through spillover effects. Zeng et al. (2019) explored the spatial spillover effects of infrastructure networks on urbanization, using a case study of the Wuhan metropolitan area in China from 2005 to 2015. The study uncovers spatial spillover effects among different localities, revealing insights into the impact of urban infrastructure on urbanization and providing valuable information for policymakers in urban planning and development. It can be concluded that these studies highlight the crucial importance of spatial econometric analysis in comprehending the complex interplay between public investment, economic growth, and regional development.

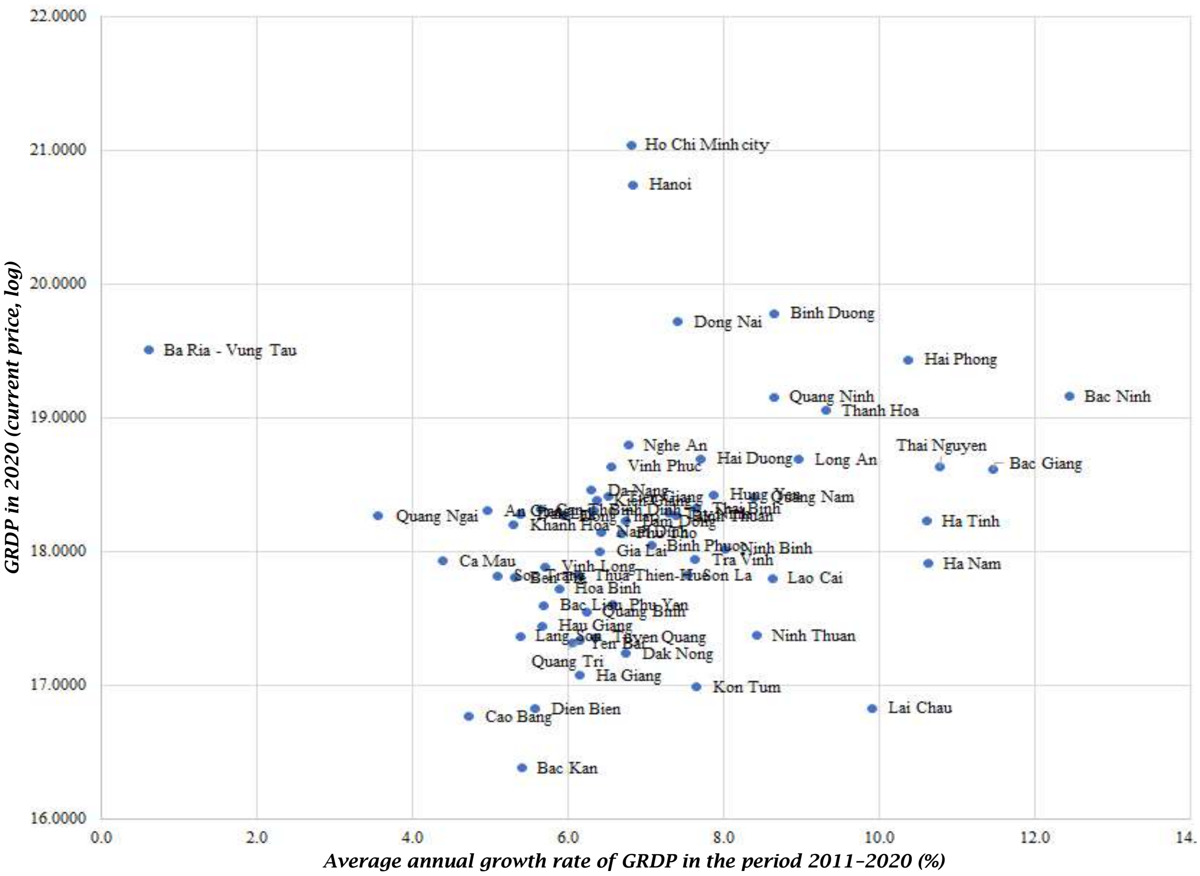
In Vietnam, Nguyen (2022) used the SDM to estimate the regional spillover effects of transportation infrastructure on Vietnam's economic growth from 2000 to 2019. The results show positive evidence in each period due to the connectivity of transportation infrastructure at the national level. Regionally, the spillover effects of transportation infrastructure significantly varied over time across Vietnam's four macro-regions: the southern region always had positive spillover effects; the northern region had adverse spillover effects during 2000–2009 and positive effects during 2010–2019; the central region had negative spillover effects in both periods; in the case of the Mekong Delta, negative spillover effects were observed after 2010. This analysis shows that changes in spillover effects between regions are closely related to the shifts in production factors in Vietnam over the past two decades. Other existing studies in Vietnam have primarily focused on the direct effects of public investment without accounting for spatial spillover effects, our study fills this research gap by incorporating spatial econometric techniques to provide a better understanding of whether the effects of public investment extend beyond the invested region, shedding light on the spatial dynamics of economic growth in Vietnam.

2.2. Economic growth among provinces and decentralized public investment in Vietnam

2.2.1. Different economic growth among provinces

In the period 2011–2020, the Vietnamese economy saw a remarkable recovery after being negatively affected by the financial crisis and the world economic recession in 2008–2009. The economic scale of Vietnam in 2020 reached Vietnamese dong (VND) 6,293.1 trillion, and the gross domestic product (GDP) per capita reached VND 64.4 million/person. The average economic growth of the whole period 2011–2020 reached 6%/year, lower than the planned target of 6.5–7%, but these are still positive results in the context of the world economy facing many difficulties and being affected by the epidemic.

Figure 1. Province's average economic growth rate in the period 2011–2020



Source: Authors' elaboration based on General Statistics Office (GSO, 2020).

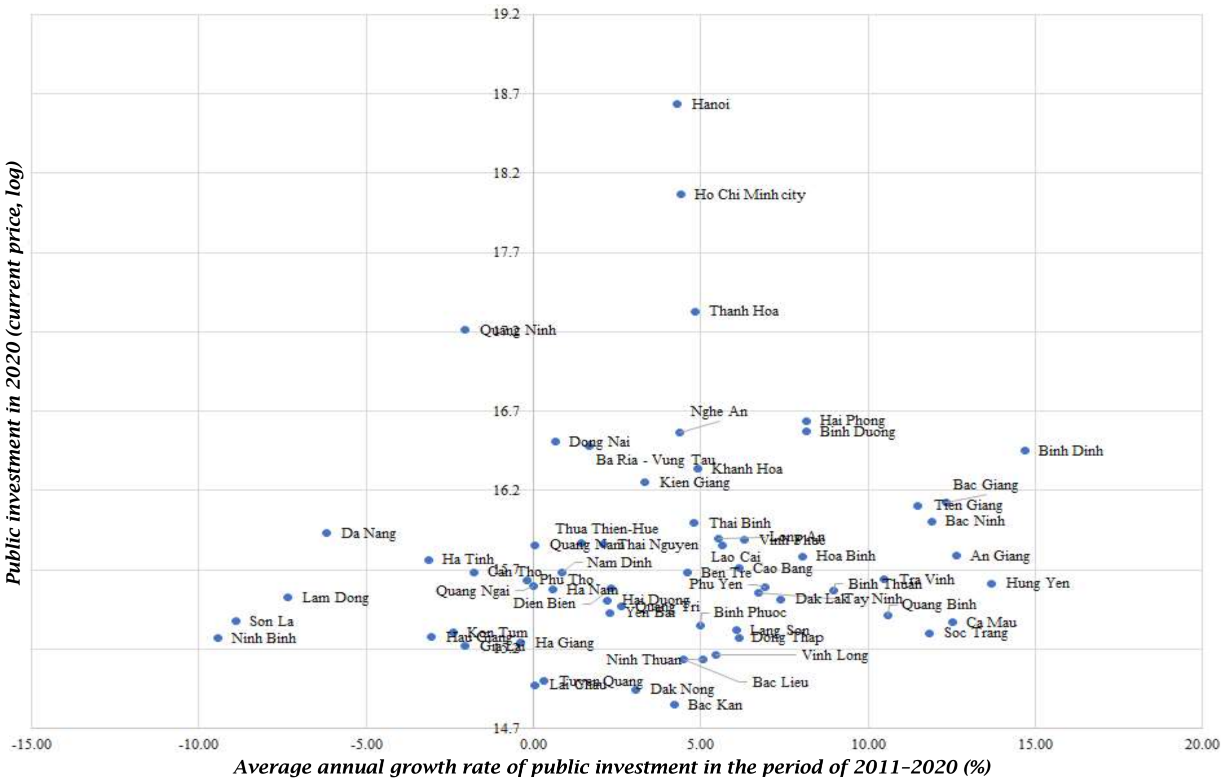
As shown in Figure 1, the growth rates of provinces exhibit variation. While economic centers like Hanoi and Ho Chi Minh City maintained the growth rate at the average level, emerging cities with high concentrations of industrial parks like Thai Nguyen, Bac Ninh, Hai Phong, or Bac Giang have observed high growth rates. On the other hand, provinces with lower economic scale had a relatively slower pace, mainly seen in the provinces of the Northwest Northern Mountainous region such as Bac Kan, Cao Bang, Dien Bien, Ha Giang, and Lang Son, where growth rates fall below the national average of 6%/year. The uneven development among provinces in Vietnam requires the attention of policymakers, including the public investment field.

2.2.2. Decentralized public investment in Vietnam

Considering public investment efficiency as a crucial factor driving future economic development, in recent years, the Vietnamese Government has undertaken commendable efforts to enhance public investment policies and laws. Before 2003, Vietnam did not have a specific law on public investment management. The adjustment of public investment activities was mainly carried out by sub-law documents. Until 2014, the adjustment of public investment activities is mainly carried out through several laws such as the Law on Construction, the Law on Budget, the Law on Bidding, and sub-law documents including Decree 16/2005/ND-CP of the Government. From year 2014 to now, Vietnam has made significant progress in public investment implementation and management. Law on Public Investment in 2014 takes effect to implement regulations on the management and use of public investment capital and state management of public investment. The National Assembly approved the Law on Public Investment on June 13, 2019. The president signed the order announced on June 27, 2019. The law takes effect on January 1, 2020. The Public Investment Law of 2019 has many innovative contents compared to the Law on Public Investment of 2014 which was revised in 2018, to complete the legal basis system and improve the efficiency of public investment activities for public investment. Given the policy reform, total social development investment capital reached VND 2.16 trillion in 2020 and achieved an average growth rate of 6.5% per year in the 2011–2020 period.

It should be noted that coupling with the decentralization process of Vietnam since Doi Moi (Baum, 2019), the decentralization of public investment has been promoted, under which provincial governments are entitled to decide on public investment projects in specific categories (Anh, 2016). Figure 2 below demonstrates the differences between provinces in public investment. Public investment is concentrated mainly in big cities such as Hanoi, Ho Chi Minh City, Quang Ninh, and Hai Phong, etc. Hanoi accounted for 34.2% in 2020, an increase of 15.68% compared to 2010. Followed by Ho Chi Minh City, public investment capital using 19.4% of the country's total public investment, an increase of 9.28% compared to 2010. It is noteworthy that some other cities are experiencing rapid public investment growth in recent years such as Thanh Hoa, accounting for 9.27%, which increased by 5.34% compared to 2010.

Figure 2. The average growth rate of public investment in the period 2011–2020



Source: Authors' elaboration based on GSO (2020).

Motivated by preliminary observations regarding variations in economic growth rates and public investment growth rates among provinces in Vietnam, this paper aims to provide insights into the impact of public investment on the growth rates of provinces, adopting a spatial approach.

3. RESEARCH METHODOLOGY

3.1. Model specification

Cobb and Douglas (1928) proposed the Cobb-Douglas production function and this model has been widely used in research related to macroeconomics. Suppose the Cobb-Douglass production function for a province in Vietnam has the following form:

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{\beta} \quad (1)$$

where, *Y, K*, and *L* are output, labor, and capital, respectively; α and β are the output elasticities of capital and labor, respectively; *A* is total factor productivity; *t* is the time of year *t* and *i* is province *i*.

Because *K* capital is formed from public (government) investment (*Ig*), private investment (*Ip*), and foreign direct investment (*FDI*). Replacing the capital *K* with the components in Eq. (1), the model can be written as follows in Eq. (2).

$$Y_{it} = A_{it}Ig_{it}^{\alpha_1}Ip_{it}^{\alpha_2}fdi_{it}^{\alpha_3}L_{it}^{\beta} \quad (2)$$

Taking the $Log\alpha$ on both sides of Eq. (2), the research gets the estimated model as follows:

$$lnY_{it} = A_{it} + \alpha_1 lnIg_{it} + \alpha_2 lnIp_{it} + \alpha_3 lnfdi_{it} + \beta lnL_{it} + u_{it} \quad (3)$$

Acknowledging the potential impact of institutional quality on provincial economic growth in Vietnam (Phuong, 2016), the study contemplates the inclusion of the Provincial Competitiveness Index (PCI) as an exogenous variable. Therefore, Model 3 is rewritten as follows:

$$lnY_{it} = A_{it} + \alpha_1 lnIg_{it} + \alpha_2 lnIp_{it} + \alpha_3 lnfdi_{it} + \eta lnL_{it} + \gamma lnPCI_{it} + u_{it} \quad (4)$$

In simple, Model 4 can be written as follows:

$$Y_{it} = c + \beta X_{it} + u_{it} \quad (5)$$

In which, *X* is a set of independent variables of Model 5 including *Ig, Ip, FDI, L*, and *PCI*.

Considering the spatial impact in Model 5, it gets:

$$Y_{it} = a + \rho \sum_{j=1}^{n} w_{ij}\, y_{it} + \sum_{i=1}^{K} X_{itk}\,\beta_k + \sum_{k=1}^{K}\sum_{j=1}^{n} w_{ij}\, X_{jtk}\theta_k + \tau_i + \xi_t + v_{it} \quad (6)$$

where,

- $v_{it} = \lambda \sum_{j=1}^{n} m_{ij}\, v_{it} + \varepsilon_{it}$;
- $\varepsilon \sim (0, \sigma^2 I)$;
- $i, j = 1, 2, \ldots, n$;
- $i \neq j$ and $t = 1, 2, \ldots, T$.

In which, *Y* and *X* are denoted above. *W* is the spatial weight matrix. α is constant. The parameters ρ are the spatial autoregressive coefficient, β and θ are the coefficients and spatial coefficients that represent the impact of the independent variables on the dependent variable, respectively.

From Model 6, it performs tests to obtain a suitable spatial econometric model based on the following criteria:

- If the $\theta = 0$ model is the spatial autoregressive model with autoregressive disturbances (SAC). This model combines a spatial lag of *Y* and the spatial error component.
- If the $\lambda = 0$ model is the SDM. This model includes spatial lags of *X* and *Y*, the spatial error component does not exist in the model.
- If $\theta = 0$ and $\lambda = 0$ model is the spatial autoregressive (SAR) model. This model is only a spatial lag of *Y*.
- If $\rho = 0$ and $\theta = 0$ model is the spatial error model (SEM). This model is only the spatial error component.
- If $\rho = 0$, $\theta = 0$, and $\tau_i = \psi \sum_{j=1}^{n} w_{ij}\,\tau_i + \zeta_i$ model is the generalized spatial panel random effects model (GSPRE).

3.1.1. Building weight matrix

The most common tool to measure the spatial correlation between objects is Moran's I index according to Moran's (1950) test. In Vietnam, there are 63 provinces/cities with the characteristics of stretching and therefore, the topic is selected as a spatial unit by the administrative unit at the provincial headquarters being the geographical location. In this paper, the first-order contiguous matrix with a contiguous scale will be used for calculations in this model. This is a common form of spatial matrix applied by many studies. Accordingly, assuming the province is adjacent to two other provinces, the value in the matrix calculated on average for each province is ½.

3.1.2. Spatial dependence and spatial lag testing

To test for the existence of spatial lag dependence and spatial lag independence in the panel model, the research uses the null hypothesis H_0: $\rho = 0$ (no existence of spatial dependence) and H_0: $\theta = 0$ (no existence of spatial lag). Accordingly, the Lagrange multiplier (LM) method is used to test the model estimation for H_0 to avoid complicated problems related to the maximum likelihood (ML) estimate. In which the tests for the spatial effect and the error component of the model are based on the studies of Anselin (1988), Baltagi et al. (2003, 2007), and Baltagi and Li (2006).

3.1.3. Estimation method

There are many methods to estimate spatial econometric models using various software such as Matlab (Elhorst, 2003, 2010; LeSage & Pace, 2009) and R (Millo & Piras, 2012; Bivand et al., 2013; Arbia, 2014). In STATA, Drukker, Prucha, et al. (2013a, 2013b) developed tools related to the estimation of spatial models with ML and generalized spatial two-stage least-squares estimators for a spatial-autoregressive model with spatial-autoregressive disturbances. Belotti et al. (2017) further developed the estimation method for spatial econometric models with the quasi-ML estimation method for balanced panel data. Five types of spatial models can be estimated, including: 1) SAR, which includes two types of models: fixed-effects (FE) and random-effects (RE); 2) SDM; 3) SEM; 4) FE SAC model; and 5) GSPRE model. Additionally, both SAR and SDM models can be estimated in a dynamic form using the bias-corrected ML approach described by Yu et al. (2008) (Belotti et al., 2017).

The article implements the following steps for estimating spatial econometric models.

Initially, the SDM model is estimated with FE and RE, and the Hausman test is used to select the appropriate model. Next, a test for the spatial lag of the independent variable is conducted to check for the existence of spatial relationships of the main variable in the model. Wald tests are also used to test for the spatial relationships of other independent variables with H_0 that the spatial relationships of the independent variables are zero. If H_0 is accepted, the SAR model is selected. Then, to examine the existence of the SEM model, the article uses tests, which are Wald-type tests of smooth nonlinear (or linear) hypotheses about the estimated parameters of the most recent fit model. If H_0 is accepted, the estimation is performed with the SEM model; otherwise, the SDM model is selected. Next, to test for SAC, GSPRE, and SDM models, the article uses the statistics of the Bayesian information criterion (BIC) and Akaike information criterion (AIC). The model with the smallest value of AIC and BIC has been selected.

3.2. Data and variable description

Similar to other studies in the field, we use gross regional domestic product (*GRDP*) as a proxy for output. Besides *Ig* — the study's main focus — we use *Ip*, *FDI*, *labor*, and the *PCI* as explanatory variables. This information is extracted from the statistical yearbooks of the GSO of Vietnam and the provincial statistics offices.

Since 2017, the provincial statistical offices of central-affiliated cities and provinces shall be responsible for collecting the input information in their provinces or cities and reporting to the GSO under the Ministry of Planning and Investment to compile and announce to avoid data discrepancies between the central and local levels. Vietnam. Following the GSO, GRDP is compiled by using the production approach. The data used in this study are recalculated by the GSO according to 2010 compare prices with the unit being billion VND for *GRDP*, *Ig*, *Ip*, and *FDI*. The unit of *labor* is 1000 people.

PCI is conducted by the Vietnam Confederation of Commerce and Industry (VCCI) with support from the United States Agency for International Development (USAID) in Vietnam. This index measures and evaluates the quality of economic governance, the convenience and friendliness of the business environment, and the administrative reform efforts of provincial and city governments in Vietnam, thereby promoting the development of the private economic sector.

The descriptive statistics of variables are presented in Table 1 below.

Table 1. Descriptive statistics of variables

Variable	*Obs.*	*Average*	*Std. dev.*	*Min.*	*Max.*
Gross regional domestic product *(GRDP)*	693	59328	109500	4711	762830
Public investment *(Ig)*	693	7749	13229	1626	83159
Private investment *(Ip)*	693	9190	13475	1706	94163
Foreign direct investment *(FDI)*	693	5499	10057	0	51534
Provincial Competitiveness Index *(PCI)*	693	67	2	62	75
Labor	693	946	759	250	4747

Source: Authors' elaboration.

4. RESEARCH RESULTS AND DISCUSSION

4.1. Testing models

4.1.1. Hausman test for SDM model

Firstly, the SDM model is estimated with FE and RE. Subsequently, we use the Hausman test to assess these models. The test result shows that Prob > Chi^2 = 0.0001, leading to the rejection of H_0 as a spatial Durbin model with RE. So, SDM with FE is chosen in this case.

H_0: Difference in coefficients not systematic: $Chi^2(3) = 22.13$, $Prob \geq Chi^2 = 0.0001$.

4.1.2. Test for the spatial lag of the independent variable

The result shows that $Chi^2(1) = 35.12$ and $Prob > Chi^2 = 0.0000 < 0.05$, so it can be rejected H_0: model does not have a lag of independent variable. Therefore, the model has a spatial lag of the dependent variable.

$$[Wx]Ig = -[Spatial]rho * [Main]Ig$$

$$Chi^2(1) = 35.12 \tag{7}$$

$$Prob > Chi^2 = 0.0000$$

4.1.3. Test for SAR model or SDM model

The result indicated that $Chi^2(2) = 16.96$ and $Prob > Chi^2 = 0.0000 < 0.01$, it can be rejected H_0: model is SAR model. So, SDM is the chosen model in this case.

$$[Wx]Ig - [Wx]FDI = 0$$

$$[Wx]Ig - [Wx]Ip = 0$$

$$[Wx]Ig = 0 \tag{8}$$

$$Chi^2(2) = 15.96$$

$$Prob > Chi^2 = 0.0000$$

4.1.4. Test for SEM model or SDM model

The result indicated that $Chi^2(10) = 43.51$ and $Prob > Chi^2 = 0.0000 < 0.01$, it can be rejected H_0: model is SEM model. So, SDM is the chosen model in this case.

$$[Wx]Ig = -[Spatial]rho * [Main]Ig$$

$$[Wx]Ip = -[Spatial]rho * [Main]Ip$$

$$[Wx]FDI = -[Spatial]rho * [Main]FDI \quad (9)$$

$$Chi^2(2) = 43.51$$

$$Prob > Chi^2 = 0.0000$$

4.1.5. Test for SAC, GSPRE, and SDM models

To test the appropriate model selection among SAC, GSPRE, and SDM models, the research relies on the statistics of BIC and AIC (Belotti et al., 2017). Accordingly, if any model has smaller BIC and AIC values, it will be the chosen model (Akaike, 1974; Stone, 1979; Raftery, 1995; Sakamoto et al., 1986; Schwarz, 1978).

The result shows that the SDM model is a model that has the smallest value of AIC and BIC. So, SDM is the chosen model in this case.

Table 2. Test results for SAC, GSPRE, and SDM models

SDM model		*SAC model*		*GSPRE model*	
AIC	*BIC*	*AIC*	*BIC*	*AIC*	*BIC*
-18.015	-15.21	-56.775	-54.87	-58.71	-72.855

Source: Authors' elaboration.

4.2. Estimated result

In this section, the study estimates the SDM model using the quasi-ML econometric model to assess the impact of *Ip* and other explanatory variables on economic growth (*GRDP*).

Table 3 above shows the estimation of the SDM model with FE, excluding the effect of LeSage and Pace (2009). Given the positive and statistically significant coefficient, *Ig* has a positive impact on the province's economic growth (*GRDP*). Besides, the coefficient of *PCI* is also positive and significant, meaning that provinces' policies can promote more *GRDP* in Vietnam. To elaborate, with other factors constant, an increase of 1% in *Ig*, *Ip*, *FDI, PCI*, and *labor* can increase the *GRDP* of provinces are 0.073%, 0.581%, 0.012%, 0.131%, and 0.324%, respectively.

Given a positive and statistically significant spatial coefficient (Rho = 0.2), the study reveals a positive spillover of *GRDP* to adjacent ones when counting the spatial interactions. Notably, the coefficient *lgt_theta* = -2.32 is negative and statistically significant, showing some growth determinants (here, including *Ig, Ip, FDI, labor*, and *PCI*) across provinces that have a spatial impact.

It could be concluded from the SDM model estimation that *Ig* has a positive impact on the *GRDP* itself and also has spillover effects on neighboring provinces. This result is in line with the findings of the studies mentioned in the literature review part. After implementing the economic reforms (Doi Moi), Vietnam's capital resources have been heavily allocated to infrastructure, particularly roads, airports, and seaports. According to data from the GSO of Vietnam, in 2022, public investment (*Ig*) accounted for about 72.19% of the total social investment capital, equivalent to 24.34% of GDP.

Table 3. Estimation results of SDM spatial econometric model

Variables	*SDM-FE*
Ig	0.073***
	(0.00)
Ip	0.581***
	(0.11)
FDI	0.012*
	(0.00)
Labor	0.324***
	(0.01)
PCI	0.131*
	(0.09)
Rho	0.193**
	(0.11)
lgt_theta	-2.32***
	(0.31)
sigma2_e	0.00***
	(0.00)
Constant	2.34***
	(0.71)
Observations	693
R-squared	0.85
Number of mun	63

*Note: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.*
Source: Authors' elaboration.

4.3. Direct, indirect, and total spillover effects

In the econometric model, it is permissible to consider the complex structure of the variable that depends on the explanatory variables, and the change of the explanatory variable can affect itself, directly to other variables or also indirectly to other variables. Therefore, in the spatial econometric model, there will exist direct, indirect, and total influences between variables. LeSage and Pace (2009) show that direct effects exist in spatial econometric model regression, and they are used to measure the average changing of independent variables on dependent variables. Accordingly, the mechanism of direct marginal effect is expressed through the effects of the diagonal elements of the spatial matrix and its neighbors. Meanwhile, the indirect marginal effect measures the effect of the non-diagonal elements of these matrices. Total effects are combined the direct effects and indirect effects. According to Belotti et al. (2017), the SDM static model only has long-term direct and indirect effects with the following specific calculation equation:

$$Direct\ effect = \{(1 - \rho W)^{-1}(\beta_k I - \theta_k W)\}^{\bar{d}} \quad (10)$$

$$Indirect\ effect = \{(1 - \rho W)^{-1}(\beta_k I - \theta_k W)\}^{\overline{rsum}} \quad (11)$$

In which, $\bar{d}$ is the mean diagonal element of a matrix and $\overline{rsum}$ is the mean row sum of the nondiagonal elements.

The decomposition results of spillover effects for the SDM model are as follows below.

Table 4. Direct, indirect, and total spillover effect

Variables	*LR_Direct*	*LR_Indirect*	*LR_Total*
Ig	0.0612***	0.0231***	0.0783***
Ip	0.4913***	0.2124***	0.5876***
FDI	0.0245***	-0.0119***	0.0103***
Labor	0.3149***	0.2814***	0.3821***
PCI	0.1231***	0.5144	0.1214***

*Note: *** $p < 0.01$.*
Source: Authors' elaboration.

Table 4 presents the direct, indirect, and overall spillover effects of the spatial econometric model assessing the impact of *Ig* on *GRDP* in Vietnam's provinces. The estimation results show that the coefficients of *Ig* in the direct, indirect, and total spillover effects are positive and statistically significant. This implies that public investment not only positively affects the *GRDP* of this province, but also contributes positively to the *GRDP* of other provinces. As a developing country, public investment across provinces in Vietnam has primarily focused on economic and social infrastructure. Therefore, it is reasonable that when a province engages in public investment, it can enhance the local infrastructure and simultaneously create economic linkages between provinces, generating positive effects for provinces in proximity.

Unlike *Ig*, the *FDI* capital proves the contrast between direct and indirect (spillover) effects. While the positive direct effect of *FDI* capital indicates that an increase in *FDI* in a province will lead to *GRDP* across neighboring provinces, the negative indirect effect (spillover) implies that the growth of *FDI* in one province may reduce *GRDP* in other provinces.

In practice, in Vietnam, when FDI flows into a province, it not only utilizes local labor but also draws upon labor from other provinces. Therefore, an increase in FDI in a province results in the migration of labor from other provinces to meet the demand. Provinces experiencing an increase in FDI tend to have better GRDP, while other provinces may face a reduction in labor due to the phenomenon of labor migration, leading to diminished GRDP.

Similarly, the estimation results only show that there exists a direct impact of *PCI* on *GRDP*. This implies that provincial macro policies related to institutional reforms of the province do not have a spillover effect on the growth of other provinces.

4.4. Robustness check

The research uses different matrices to robustness check for the model. Which, the spatial matrices are built specifically as follows:

- MW1 is a first-order contiguous matrix with a contiguous scale that is defined above.
- First-order contiguous matrix (MW2): This is a simple matrix with only values of 0 and 1. In which, 1 is contiguous to neighboring provinces and 0 is non-contiguous.
- Marginal contiguous matrix (MW3): This matrix is built based on the contiguous boundary distances between provinces. The value in the matrix is the contiguous value (in km or miles) of two contiguous provinces and vice versa is 0.
- Distance matrix to three central provinces (MW4): This matrix is built based on three central provinces: Hanoi, Da Nang, and Ho Chi Minh City. The value in the matrix is measured by calculating the distance from the provinces to the central province. In which, the distance is taken as the smallest value of a province to one of the three central provinces above.
- Coordinate space matrix (MW5): This matrix is built based on the coordinates of a province according to Google Maps including longitude and latitude.

Table 5. Results of robustness check

Variables	*MW1*	*MW2*	*MW3*	*MW4*	*MW5*
Ig	0.0731	0.07439	0.07522	0.07811	0.07357
Ip	0.5814	0.57110	0.57803	0.58477	0.57325
FDI	0.0122	0.01362	0.01528	0.01812	0.01481
Labor	0.3241	0.32635	0.33110	0.33163	0.32740
PCI	0.1313	0.12610	0.12600	0.13240	0.11350
Spatial					
Rho	0.1930	0.19332	0.19682	0.21907	0.19364
Variance					
sigma2_e	0.0034	0.0035	0.0038	0.0040	0.0039

Source: Authors' elaboration.

The table above presents the results of estimating the SDM spatial econometric model for the five spatial matrices mentioned above to verify the stability of the model. The results showed that there appeared to be no difference between the estimation results of the matrices. Accordingly, the choice of matrix does not seem to affect the study results, but not by much. For example, the variation of rho is only from 0.19 to 0.22, and *sigma2_e* is only from 0.0034 to 0.004 in the models. Besides, the sign of the variables and the degree of statistical significance of the variables do not change. Therefore, the results of the model are solid and can be used to analyze the impact of *FDI* on *GRDP*.

5. CONCLUSION

The study examined the nuanced impacts of public investment on provincial economic growth counting the spatial interactions for the period 2010–2020 across 63 provinces in Vietnam. The disparities in economic growth rates and public investments among provinces raised two crucial questions: 1) whether public investment contributes to regional economic growth; and 2) whether its effect will extend beyond provincial borders to influence the economic growth of neighboring provinces. These questions highlight the relationship between public investment and regional economic growth in the context of a developing country like Vietnam and unfold the intricate spatial at play.

We have considered various spatial models for an empirical analysis, guided by test results, and selected the SDM as the most suitable one. It has proved the role of public investment in the process of economic development in Vietnam's provinces. Notably, our study illuminated the spatial interconnectedness of provinces, emphasizing economic growth and public investment in a specific province influence the economic trajectory of the adjacent provinces. Additionally, the study provides a more comprehensive exploration, besides other determinants of growth like labor and institutional environment (which is proxied by the competitiveness index), we also consider the role of foreign direct investment. The finding shows its positive influence on regional growth and direct impact on neighboring provinces. However, contrary to expectations, FDI has an adverse impact in terms of indirect spillover effects. This multifaceted analysis and the intricate dynamics between public investment, economic growth, and foreign direct investment across Vietnamese provinces call for further studies to have a better understanding of the underlying mechanism and provide policy recommendations for sustained and relatively balanced development across Vietnam.

On the limitations of the research, due to the characteristics of Vietnam's data, particularly regarding national public investment programs and projects, this article has only been able to aggregate public investment data at the provincial level. Additionally, a limitation of the spatial econometric model lies in the relative nature of the spatial matrix and the difficulty in accurately identifying the spatial spillover channels of the variables used in the model, especially the spillover channel of public investment from one province to another. For instance, public investment programs and projects like highways that run through many provinces in Vietnam pose challenges in fully calculating the benefits of this public investment at the provincial level and the potential for goods transportation between provinces. Vietnam will keep improving the institutional and policy framework for public investment in line with the new economic context in the future. Moreover, there needs to be more in-depth and detailed research on the spillover effects of public investment through specific channels and the construction of a spatial matrix that more fully reflects the spillover nature of the public investment to achieve better results, thereby providing more appropriate solutions and enhancing the efficiency of public investment capital utilization.

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