

How should public investment be structured to avoid the crowding-out effect on private investment? Valuable lessons from the Russian economy for Vietnam

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Abstract

After each economic crisis, such as the recent COVID-19 pandemic, governments have used public investment as a crucial tool to help economies recover quickly. However, a significant concern is how to structure such investments to meet the intended objectives while avoiding risks during implementation. The crowding-in/out effect of public investment on private investment remains a hotly debated topic. To address this issue, the study utilized data from 63 provinces in Vietnam over the period from 2000 to 2023. Through the use of the Cross-Sectionally Augmented Autoregressive Distributed Lag model (CS-ARDL) model and robustness checks using the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models, the research demonstrated that public investment has a crowding-in effect on private investment in the long term. Furthermore, the study identified two main causes of public investment crowding out private investment: first, when public investment exceeds the production capacity of the economy, and second, when public investment is inefficient. This conclusion is drawn from the analysis of the Russian economy. Additionally, the study employed the dynamic panel threshold model and found that if the ratio of public investment to GDP in Vietnam exceeds 8.532%, the crowding-out effect on private investment will occur. Moreover, the research also assessed the effectiveness of public investment in the context of climate change to identify shortcomings that need to be addressed immediately. These findings serve as important bases for proposing measures to improve the efficiency of public investment and avoid the crowding-out effect on private investment.

Keywords: crowding-in, crowding-out, public investment, private investment, CS-ARDL, threshold, Vietnam, Russia.

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1. Introduction

The relationship between public investment and private investment has garnered significant attention from researchers due to its dual nature. When the government borrows from the financial market to finance public investments, it leads to a sharp increase in market interest rates, thereby preventing private investors from accessing borrowed capital. Consequently, public investment can crowd out private investment (Husain et al., 2023; Maluleke et al., 2023). Additionally, each type of investment pursues different objectives; private investment typically aims for profit, whereas public investment serves social goals, such as investing in infrastructure and improving the quality of life for people, especially in remote areas where economic conditions are challenging and private investors show little interest (Iasco-Pereira, Duregger, 2024). By improving infrastructure, the investment environment enables private enterprises to reduce production costs, expand markets, and increase profits. Public investment can increase marginal productivity and crowd in private investment (Rai et al., 2024).

Public investment is an important driver for economic development, serving as a foundation for attracting and effectively utilizing private investment capital (Mourougane et al., 2016). For countries with increasing budget deficits, careful consideration must be given to public investment projects, as continuing to boost public investment may require the government to raise taxes to offset the budget deficit, which could have an adverse effect on private investment (Omitogun, 2018). Furthermore, in cases where public investment is inefficient, the budget deficit becomes more severe, leading many countries to resort to increased foreign borrowing, which in turn raises the risk of economic instability, higher inflation, and capital outflow to other countries—a scenario that many nations wish to avoid (Bom, 2017; Elroukh, 2024).

Many studies have examined the link between public and private capital formation. Some find that government spending displaces private activity (crowding-out) (Bahmani-Oskooee, 1999; Erden and Holcombe, 2005), while others conclude that it stimulates additional private activity (crowding-in) (Bahal et al., 2015; Cavallo and Daude, 2011; Tchouassi and Ngangue, 2014). The direction of the effect differs across countries, reflecting local conditions. In general, the evidence suggests that displacement is more likely when the public sector expands beyond the economy's absorptive capacity or when projects are implemented inefficiently (Khan and Kumar, 1997; Afonso and St. Aubyn, 2019).

In the post-economic crisis period, government budgets were severely affected, leading to a significant reduction in public investment, which directly contributed to economic growth declines and reduced private investment (Shankar, 2021; Elroukh, 2024). Therefore, the economy needs substantial boosts to recover from its previous state. Currently, numerous studies provide strong evidence of the significant role of public investment in the economy, particularly in the post-COVID-19 and climate change contexts (Cepparulo et al., 2024; Iasco-Pereira and Duregger, 2024). Public investment will focus on key sectors with a broad impact on the economy, such as energy, telecommunications, and infrastructure, which help accelerate the process of attracting private investment. However, if caution is not exercised in public investment projects, it could lead to adverse effects, exacerbating the economic downturn (Schweikert et al., 2014).

Our paper explores the long-term relationship between public investment and private investment in the Vietnamese economy. The study uses panel data collected from 63 provinces in Vietnam from 2000 to 2023. By applying the Autoregressive Distributed Lag model (CS-ARDL) model to explore this long-term relationship, the study also conducts robustness checks using the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models. After demonstrating that public investment crowds in private investment, the study further collects information and draws valuable lessons from the Russian economy to help Vietnam avoid the crowding-out effect of public investment on private investment. To provide clear figures before making recommendations to public investment managers, the study employs the dynamic panel threshold model and finds that if Vietnam's public investment/GDP ratio exceeds 8.532%, it will lead to a crowding-out effect on private investment. With the data collected, the study identifies limitations in public investment management in Vietnam. Combining lessons learned from the Russian economy and the shortcomings identified in public management, the study proposes several policies to improve the efficiency of public investment and avoid the crowding-out effect on private investment. Despite the results achieved, there are still some gaps that need to be addressed in future research, such as examining the impact of corruption and climate change on the quality of public investment projects, which in turn affects private investment in the future.

2. Literature review

2.1. Theoretical framework

Before turning to the empirical evidence, it is important to outline the main theoretical lenses through which the interaction between public and private capital has been studied. Economic thought offers several distinct but complementary perspectives. These frameworks highlight the channels through which government spending may either stimulate or displace private activity, and they provide the foundation for the empirical models adopted in this paper. The following subsections briefly review three major approaches: Keynesian economics, Neoclassical economics, and theories of economic behavior.

Keynesian economics. In Keynes (1936), he argued that the economy suffers from insufficient employment. Consequently, governments should stimulate aggregate demand through public investment, thereby boosting the economy and creating more jobs. Proponents of Keynesian economics believe that expansionary fiscal policies, including tax cuts and increased government spending, can enhance private-sector markets via the fiscal multiplier effect. This effect may imply a crowding-in of private investment into the economy (Lavoie, 2014). In Aschauer (1989), public investment in infrastructure was found to positively impact productivity and encourage private investment. Barro (1990) further developed this theory by emphasizing that public expenditure in areas such as infrastructure, education, and research and development can improve productivity and the efficiency of private investment, ultimately accelerating economic growth. Finally, theoretical and empirical findings from multisectoral modelling frameworks suggest that Keynesian-type multiplier effects depend to a large

extent on the physical composition of government spending and that, in general, there are non-monotonic relationships between these effects and the interest rate (Kurz, 1985; Mariolis and Ntemiroglou, 2023).

Neoclassical economics. Neoclassical economists adopt a cautious stance when evaluating the role of public investment in private investment. They suggest that public investment can either crowd out or stimulate private investment. Friedman (1962) argued that public investment was often inefficient, leading to a crowding-out effect as it competes for resources with private investment, thereby reducing overall productivity. In contrast, free markets are typically seen as more effective at resource allocation than government intervention. In Tobin's study (1969), although he adhered to Keynesian principles, he was influenced by neoclassical thought and acknowledged that public investment could have dual effects. It may either stimulate or crowd out private investment, depending on the financial structure of the economy and how public investments are financed—whether through taxes, borrowing, or money creation. If the government employs expansionary fiscal policies, especially by borrowing to finance expenditures, it can drive up interest rates, significantly affecting the availability of funds from financial markets for private investments (Sineviciene and Vasiliauskaite, 2012). This concern was echoed by Alesina and Perotti (1997), who emphasized that inefficient public investment and severe budget deficits pose substantial risks of crowding out private investment.

The theory of economic behavior. Economists belonging to this school of thought have presented arguments from various perspectives regarding the impact of public investment on private investment, rooted in psychological, cognitive, and emotional factors influencing investment decisions. Akerlof and Shiller (2009) emphasized the role of psychology and emotions in economic decisions, asserting that large-scale public investment projects by the government can evoke positive or negative sentiments among private investors. When public investment is perceived as beneficial to the economy, it stimulates private investment. Conversely, wasteful or non-transparent public investment erodes trust among private investors, leading to crowding-out effects. Aligned with this perspective, Kahneman and Tversky (1979) argued that public investment improves the investment environment, reduces market risks, and may encourage private enterprises to enhance their investment efforts. Private investors can introduce investment opportunities to other firms, fostering collaboration and mutual support in production and business processes. Furthermore, private enterprises often carefully assess, evaluate, and mitigate risks in their business activities. Thus, private firms may respond negatively to public investment if they perceive it as fostering unhealthy competition or distorting markets, particularly in sectors where both public and private investments coexist (Shleifer and Vishny, 1994). Additionally, in countries where private enterprise investment decisions heavily rely on transparency and trust in the government, especially confidence in commitments to provide support during hardships, the level of trust plays a pivotal role (Fukuyama, 1995). The concept of herd psychology is also mentioned in this context (Banerjee, 1992). Private enterprises tend to follow market trends and imitate what the majority are doing. Thus, positive signals from the market and successful public investment in improving the investment environment and reducing risks for businesses can attract both domestic and foreign private investors. This creates spillover effects, accelerating economic development. Otherwise, adverse effects may occur.

2.2. *Previous empirical studies*

The impact of public investment on private investment is a relatively complex process, both in the short term and in the long term. When governments significantly increase public investment, it can boost private investment, but the effects vary across countries (Afonso and St. Aubyn, 2019; Bom, 2017). This variation arises because the implementation of public investment depends on numerous factors that differ across countries, such as government expenditure components, capital management capacity, and the industries selected for investment. This was demonstrated in the study by Laopodis (2001), which examined four countries—Ireland, Greece, Portugal, and Spain—and found that public investment only enhances private investment attraction in certain cases, while in others, it has the opposite effect on private investment. Furthermore, many countries, in an effort to increase public investment, are willing to borrow additional funds, leading to higher lending interest rates and reduced private investment demand (Serven and Solimano, 1993). Public investment is often financed by the state budget. Therefore, economists predict that budget deficits will lead to a decrease in public investment and negatively impact private investment. However, this was proven incorrect by Fröhlich (1985).

Several studies have shown that public investment plays a significant role in economic development, particularly during periods of recession. Although the state budget is experiencing substantial deficits, many governments are still willing to supplement public investment by restructuring expenditures and borrowing domestically and internationally to continue implementing public investment projects. To support this view, Argimon et al. (1997) studied 14 OECD countries and demonstrated that there is a significant crowding-in effect of private investment driven by public investment through infrastructure investments, which enhances productivity in private investment. This study also indicated that countries attempting to reduce budget deficits by cutting public investment will severely impact growth prospects and the accumulation of private investment capital.

In the studies of Keynes (1937) and Solow (1956), it was suggested that an increase in investment leads to higher demand for input factors, which in turn causes prices to rise. However, during this period, there were many statistical limitations, making it difficult to clearly determine the extent to which public investment crowds out or crowds in private investment. As statistical methods advanced, Bennett's (1983) study, using data from the United States, found that public investment does not affect private investment. In a recent study, Kandil (2017) used data from developed and developing countries to examine the cyclical response of macroeconomic variables to the expansion or contraction of private and public investment. The study found that in developing countries, public consumption strongly influenced economic growth, while in developed countries, private consumption had a more substantial impact on economic growth. Thus, the mechanisms by which private and public investment affect the economy differ across countries.

Funashima and Ohtsuka (2019) show that effects vary by region: in urban Kanto, government consumption exhibits partial crowding-in on private consumption, while in rural Shikoku, public investment shows partial crowding-in on private consumption; moreover, once spatial spillovers are accounted for, crowding-out from public investment is negligible. This underscores the signifi-

cant role of the government in limiting the crowding-out effect of public investment on private investment and the need to consider the spatial spillover effects of public policies to stimulate private investment demand.

To further clarify the crowding-out or crowding-in effect of public investment on private investment, Khan and Kumar (1997) used data from 95 developing countries and found that public investment in infrastructure helps attract more private investment in the long term. However, the degree of impact varies over time and by region. Therefore, policymakers need to pay attention to the level and structure of public investment at different stages and in specific regions. Furthermore, private investors are highly concerned about the infrastructure of localities, as good infrastructure helps reduce production costs and access new markets, leading to higher profits. Therefore, through public investment, governments will invest heavily in infrastructure, which helps boost the attraction of private investment in the long term (Ang, 2009; Makuyana and Odhiambo, 2017). In the study by Xu and Yan (2014), using data from 1980 to 2011 in China, public investment was divided into two types: first, the provision of public goods and infrastructure, and second, investment in private industry and commerce. The study results showed that investments in public goods and infrastructure had a crowding-in effect on private investment, as these investments improve the efficiency of private investment, reduce production costs, and provide opportunities to access new markets. Meanwhile, public investment in private industry and commerce creates a crowding-out effect on private investment by increasing competition between private and state-owned enterprises, raising input costs such as raw materials and production capital, and leading to overlapping and unhealthy competition between enterprises. This is highly detrimental to the economy (Shankar and Trivedi, 2021).

In addition to considering the structure of public investment, the efficiency of public investment projects is also a topic of significant research interest. According to Melnikov (2021), public investment projects often focus more on political objectives than economic ones, with many projects being inefficient. This results in public investment not stimulating private investment and contributing very little to economic growth. Moreover, these investments are primarily funded through national welfare funds, leading to high inflation. The central bank is forced to raise interest rates to counteract this situation, but this makes it difficult for private investors to access bank credit. Additionally, low public investment efficiency significantly reduces the ability to maintain price stability and economic stability (Vlasov and Sinyakov, 2020). Therefore, governments need to choose investments wisely, using modern approaches to calculate the costs, benefits, and potential risks of public investment. Furthermore, partnering with private investors is a suitable measure to share risks and manage public investment more effectively (Melnikov, 2021).

Currently, rapid climate change is having a significant impact on the economy and the quality of life. Therefore, public investment, especially in infrastructure, should not only focus on quantity but also pay attention to the quality of infrastructure through cost-benefit analysis. Infrastructure projects are increasingly exposed to harsh climatic conditions, making them vulnerable. As a result, the risks posed by climate change are a significant threat to public investment-supported infrastructure projects and economic development (Schweikert et al., 2014). Government agencies have not yet fully considered climate change adaptation activities, especially long-term plans to address this issue. Although

awareness of this problem is increasing, it has received little attention in the planning, implementation, operation, and maintenance of infrastructure. Overlooking the impacts of climate change would be a significant omission in the strategic planning of public investment in the coming years for each country (Hambly et al., 2013; Keener et al., 2014).

In developing countries, due to a lack of technical knowledge, capital, and mechanisms to support effective projects, public investment projects often face challenges such as inadequate maintenance, poor enforcement of construction material quality, and evaluation indicators influenced by external factors such as weather conditions. This has greatly contributed to the reduced success rate of public investment projects in the long term (Dabla-Norris et al., 2012). Numerous studies have evaluated the impact of climate change on the quality of infrastructure in each country. These studies all indicate that climate change poses a significant threat to the current and future lifespan and capacity of infrastructure, including high costs for adaptation, maintenance, and repair and potential negative impacts on the operation of a nation's infrastructure (Keener et al., 2013; Hambly et al., 2013).

Therefore, in the design and approval of public investment projects, public investors must consider the impact of climate change on these projects, such as listing weather conditions and assessing the impact of each change, to develop risk prevention plans (Su and Bui, 2017; Nguyen et al., 2024). This work requires considerable time and a large amount of information to be collected, and accurate forecasts are needed to determine the total cost of construction, maintenance, and use. Secondly, in the context of unpredictable weather conditions, many projects that significantly affect people's lives need comprehensive contingency plans and strict quality control plans to prevent waste and ensure usability in the event of an incident (Shiferaw, 2024; Espinoza and Presbitero, 2022).

Thus, it can be seen that public investment can have either a positive or negative impact on private investment. Governments typically expect that increased public investment will attract more private investment capital by improving the investment environment, providing good infrastructure, reducing production costs, and enhancing the competitiveness of private enterprises (Phuong, 2020; Vu, 2024). However, not all public investments positively affect private investment; in cases where public investment is directed toward commercial goods and services, where competition among private enterprises is fierce, this may lead to an adverse reaction to the intended objectives (Tuan and Dung, 2023; Diem, 2024). However, when public investment exceeds the state's budget capacity, leading to increased budget deficits funded by domestic and foreign borrowing, many governments will resort to raising capital to continue financing ongoing investments, which may increase interest rates in the money market and negatively affect private investors' decisions (Rai, 2024; Van Bon, 2019). Moreover, the adverse impact of public investment on private investment is not only related to the structure of investment but also significantly depends on the scale of investment. An expanded public investment scale introduces a large amount of currency into circulation, potentially leading to a situation where the economy's production capacity is exceeded, causing inflation and negatively impacting the economy. Therefore, public investment decisions need to be carefully considered based on various factors and the actual economic situation to make appropriate investment decisions (Afonso and St. Aubyn, 2019; Elroukh, 2024).

Table 1
Description of variables.

Variables	Notation	Calculation, %	Previous research
<i>Dependent variable</i>			
Private investment	PI	Private investment/GDP	Rai et al. (2024); Iasco-Pereira, Duregger (2024); Omitogun (2018); Ouédraogo et al. (2019); Elroukh (2024)
<i>Independent variables</i>			
Gross domestic product	GDP	Annual growth rate of local real GDP	Omitogun (2018); Elroukh (2024); Marcos, Vale (2024); Maluleke et al. (2023)
Trade openness	OP	Import & Export/GDP	Iasco-Pereira, Duregger (2024); Ouédraogo et al. (2019); Maluleke et al. (2023)
Credit to the private sector	CR	Credit to the private sector/GDP	Ouédraogo et al. (2019); Iasco-Pereira, Duregger (2024); Maluleke et al. (2023)
Recurrent expenses	RE	Recurrent expenses /GDP	Rai et al. (2024); Omitogun (2018)
Labor	LB	Percentage of local labor force aged over 15/ Total population	Iasco-Pereira, Duregger (2024)
Public investment	PU	Public investment /GDP	Rai et al. (2024); Iasco-Pereira, Duregger (2024); Omitogun (2018); Ouédraogo et al. (2019); Elroukh (2024)

Source: Compiled by the authors.

3. Data and research model

3.1. Data

The data used in the research model comprise provincial-level data from Vietnam, collected from 2000 to 2023. The data for the variables were gathered by the authors from the General Statistics Office of Vietnam (GSO). Additionally, to compare public investment in Vietnam with that in Russia, the public investment data for Russia was collected by the authors from the Russian Federal State Statistics Service. After collection, the researchers conducted classification and calculations. The definitions and measurements of the variables in the model are described in Table 1.

3.2. Research model

To empirically investigate the relationship between public and private investment, this study applies a sequence of econometric procedures designed for heterogeneous panel data with potential cross-sectional dependence. The approach begins with preliminary specification tests (cross-sectional dependence, slope homogeneity, unit roots, and cointegration) to ensure that the data meet the assumptions required for reliable estimation. Building on these diagnostics, the analysis proceeds with long-run estimators (CS-ARDL, DOLS, FMOLS) and then incorporates nonlinear dynamics through a dynamic panel threshold model. Finally, panel causality tests are employed to identify the direction of interactions among the key variables.

Cross-sectional dependency test. First, to estimate the panel data model, it is necessary to test for cross-sectional dependency (CSD). This test examines whether the variables are independent of each other. This step is crucial for obtaining accurate estimation results. In this study, the CSD test proposed by Pesaran (2007) was used.

Slope homogeneity test. After identifying the CSD issue, the next step is to determine the slope homogeneity of the variables included in the model because this phenomenon arises from the different characteristics of each region, leading to variations in slope. To test this, we used the method proposed by Pesaran and Yamagata (2008).

Panel unit root tests. To date, a second-generation panel unit root test has been introduced. The first-generation panel unit root test assumes that the cross-sectional units are independent and have homogeneous slopes. This assumption can lead to biased estimation results. To address this issue, the study employed the second-generation unit root tests, CIPS and CADF, as suggested by Pesaran (2007).

Panel cointegration test. To test for long-term cointegration, the study used the methods proposed by Pedroni (1999) and Kao (1999). These methods allow for the study of heterogeneous panels where the slope coefficients are not uniform.

To explore the long-term relationship between public investment and private investment, the study employed three econometric methods: the CS-ARDL model (equation 1) as proposed by Chudik and Pesaran (2015), the DOLS estimator (equation 2) developed by Pedroni (2001a), and the FMOLS estimator (equation 3). The FMOLS was originally developed by Phillips and Hansen (1990) and extended to panel settings by Pedroni (2001a, 2001b), and has also been further applied and evaluated in panel data contexts by Kao and Chiang (2001). These methods are advantageous for addressing endogeneity and serial correlation issues (Moutinho and Robaina, 2016). From a technical standpoint, to minimize endogeneity, DOLS employs a parametric technique, whereas FMOLS uses a non-parametric approach. As a result, DOLS estimates are generally more efficient than those of FMOLS. Additionally, DOLS is considered effective in cases where there is cross-sectional dependence among entities (Pattak et al., 2023). For robust results, the study utilized the CS-ARDL model to compare the long-term relationship between public and private investment with other models. The CS-ARDL model was chosen for the following reasons: first, it allows for the estimation of variables with different levels of stationarity; second, it addresses issues of endogeneity and slope heterogeneity; and third, it is effective in cases of cross-sectional dependence by using cross-sectional averages as estimation tools. Furthermore, the CS-ARDL model helps to effectively control for unobservable factors in measuring long-term effects

$$\Delta y_{i,t} = \varphi_i (\Delta y_{i,t-1} - \theta'_i X_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta X_{i,t-j} + \alpha_i \bar{y}_{t-1} + \gamma'_i \bar{x}_{t-1} \sum_{j=0}^{p-1} \varphi_{ij} \Delta \bar{y}_{t-j}. \quad (1)$$

where: $\bar{y}_t = \frac{1}{N} \sum_{i=1}^N y_{it}$ and $\bar{x}_t = \frac{1}{N} \sum_{i=1}^N X_{it}$ denote the cross-sectional averages; $i = 1, \dots, N$ — cross-sectional units; $t = 1, \dots, T$ — time periods; y_{it} —dependent variable; X_{it} —vector of explanatory variables.

By including these averages, the CS-ARDL estimator accounts for cross-sectional dependence from unobserved common shocks and provides consistent long-run coefficients.

For robustness, the study also applies DOLS estimator:

$$y_{i,t} = \mu_i + \beta'_i X_{it} + \sum_{l=-L}^L c'_{il} \Delta X_{i,t-l} + \varepsilon_{it}, \quad \hat{\beta}_{DOLS} = \frac{1}{N} \sum_{i=1}^N \hat{\beta}_i^{DOLS}, \quad (2)$$

where: l denotes the lag/lead index. The summation $\sum_{l=-L}^L$ indicates that the model incorporates both lagged and lead values of the first-differenced regressors ΔX_{it} .

The DOLS estimator corrects for possible endogeneity and serial correlation by including leads and lags of the first-differenced regressors. This approach delivers unbiased and efficient estimates of the long-run cointegrating relationship between public and private investment.

In addition, FMOLS estimator is employed to further validate the robustness of the long-run relationship. Use of FMOLS in panel cointegration analysis has been suggested by Pedroni (2001a, 2001b). Panel FMOLS has several advantages: it allows for serial correlation, addresses endogeneity, and accounts for cross-sectional heterogeneity. Moreover, it provides both within—dimension and between—dimension estimates. The pooled FMOLS estimator is defined as:

$$\hat{\beta}_{FMOLS} = \left(\sum_{i=1}^N \hat{L}_{22i}^{-1} \sum_{t=1}^T (X_{it} - \bar{X}_i)^2 \right)^{-1} \sum_{i=1}^N \hat{L}_{11i}^{-1} \hat{L}_{22i}^{-1} \left(\sum_{t=1}^T (X_{it} - \bar{X}_i) y_{i,t}^* - T \hat{\delta}_i \right), \quad (3)$$

$$\text{where } y_{i,t}^* = (y_{it} - \bar{y}_i) - \frac{\hat{L}_{21i}^{-1}}{\hat{L}_{22i}^{-1}} \Delta X_{it} + \frac{\hat{L}_{21i}^{-1} - \hat{L}_{22i}^{-1}}{\hat{L}_{22i}^{-1}} \beta (X_{it} - \bar{X}_i) \quad (4)$$

$$\text{and } \hat{\delta}_i = \hat{\Gamma}_{22i} + \hat{\Omega}_{21i}^0 - \frac{\hat{L}_{21i}}{\hat{L}_{22i}} (\hat{\Gamma}_{22i} + \hat{\Omega}_{21i}^0). \quad (5)$$

where \hat{L}_{22i} , \hat{L}_{21i} , $\hat{\Gamma}$, $\hat{\Omega}$ are the long-run covariance components defined in Pedroni (2001a, 2001b). This formulation ensures that FMOLS produces consistent and asymptotically unbiased estimates of the long-run coefficients, serving as a complementary robustness check alongside DOLS.

Dynamic panel threshold model: To examine the nonlinear impact of public investment on private investment, the study employed the dynamic panel threshold model proposed by Seo and Shin (2016). This model is based on an endogenous threshold variable and addresses the limitations of the static panel threshold model in the following ways: First, since economic variables are determined based on their past behaviors, it is necessary to include the lagged coefficient of the dependent variable in the regression equation, thereby transforming the static panel model into a dynamic panel model. Second, using the static panel threshold model may lead to biased estimates because this model requires the threshold variable to be completely exogenous. Additionally, this study uses the dynamic panel threshold model to assess how the impact of public investment on private investment changes across different levels of public investment development.

Panel causality test: For the panel data, the study employed the Dumitrescu and Hurlin (2012) causality test to identify the causal relationships between the variables. The panel causality test equation can be articulated as:

$$y_{i,t} = a_i + \sum_{k=1}^K \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^K \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t}, \quad (6)$$

where K stands for the lag length. Moreover, the panel for the test is a balanced panel. $\gamma_i^{(k)}$, which is an autoregressive parameter, and $\beta_i^{(k)}$, which is the regression coefficient pitch can change among the groups. According to the null hypothesis, there is no causality in the panel. Alternative hypotheses show causality in the smallest cross-section element. We can test hypothesis based on an average Wald statistic as presented in the following equation:

$$W_{n,t}^{Hnc} = \frac{1}{N} \sum_i^N W_{i,t}. \quad (7)$$

Hypothesis is defined as: the average statistic $W_{n,t}^{Hnc}$ associated with the null Homogeneous Non-Causality (Hnc) where $W_{i,t}$ denotes the individual Wald statistics for the i th cross-section unit corresponding to the individual test $H_0: \mu_i = 0$.

4. Results and discussion

4.1. Public investment in Vietnam

Vietnam is a developing country; therefore, agriculture is one of the key sectors in its economy. According to the General Statistics Office of Vietnam (2023), agriculture accounted for 11.96% of Vietnam's GDP, with export values reaching \$28.15 billion for key commodities such as rice, vegetables, coffee, and cashews. However, in recent years, Vietnam has faced significant challenges due to climate change. According to the World Bank (2022), agricultural losses caused by climate change in Vietnam are projected to reach 5.6–6.2% of GDP by 2030 and 7.6–10.6% by 2050, depending on climate scenarios. Drought alone is estimated to cause 20% to 30% of these losses, reducing crop yields and food production and severely impacting the livelihoods of residents. Moreover, climate change alters the living conditions of various species, leading to the extinction of some species and the proliferation of harmful ones. For coastal provinces, flooding and rising sea levels result in the loss of agricultural land, reducing land utilization frequency from 3–4 cycles per year to only 1–1.5 cycles per year (World Bank, 2022; Dinh et al., 2023). Saline intrusion is particularly severe in the Mekong Delta. If sea levels rise by 1 meter, approximately 1.77 million hectares of land (45% of the Mekong Delta's area) would be affected by salinity, leaving about 85% of the population in the region in need of agricultural support. In response to these challenges, the Vietnamese government has increased public investment in agriculture, particularly in irrigation systems (Tang, 2023). According to the General Statistics Office (2023), Vietnam has over 86,200 irrigation works, including 6,750 reservoirs, 592 dams, and 19,416 pumping stations. This irrigation infrastructure ensures water supply for approximately 7.26 million hectares of rice cultivation out of 7.68 million hectares (95%), advanced and water-saving irrigation for nearly 0.53 million hectares of upland crops out of 3.4 million hectares, and water for aquaculture over 686,600 hectares and around 6.5 billion

cubic meters for domestic and industrial use. The system also provides flood control for residential areas, secures agricultural production, and drains approximately 2 million hectares of agricultural and urban land while controlling salinity for around 1 million hectares of farmland. One of the significant challenges in implementing irrigation projects is the substantial capital required and the long investment period. For instance, the Cai Lon—Cai Be irrigation project, the largest in Vietnam to date, required nearly 20 years of research before implementation. To address these issues, the Vietnamese government has prioritized investment in research to develop drought- and salt-tolerant crop varieties and supported the transition of agricultural structures from water-intensive crops to high-value economic crops such as cashew, coffee, and mango. Additionally, the government provides financial support to farmers through subsidies or preferential credit sources. This serves as a significant incentive for farmers, particularly those living in remote areas where agriculture is the primary means of livelihood, to improve their living conditions. Furthermore, these public investments contribute to sustainable agricultural development in Vietnam, ensuring food security for the future (Dinh et al., 2023; Giles et al., 2021).

Public investment in transportation has been one of the key drivers of Vietnam's economic development in recent years. According to the General Statistics Office of Vietnam (2024), Vietnam's road network currently spans a total length of 570,448 km, with national highways accounting for 24,136 km, expressways for 816 km, and provincial roads for 25,741 km. The railway network extends over a total length of 3,163 km, with average speeds of 50–60 km/h for freight trains and 80–90 km/h for passenger trains. Vietnam operates 33 civilian airports, including 11 international airports and 12 domestic airports. Noi Bai International Airport in Hanoi and Tan Son Nhat International Airport in Ho Chi Minh City are the two main hubs for international destinations, while the 12 domestic airports connect all regions and most provinces in Vietnam. By 2030, Vietnam plans to construct five additional airports in the provinces of Son La, Lao Cai, Quang Tri, Binh Thuan, and Dong Nai. To achieve these results, public investment in transportation infrastructure has consistently accounted for between 40% and 47% from 2010 to 2023 (Fig. 1). Despite the achievements, Vietnam's transportation system faces significant challenges stemming from its lack of synchronization,

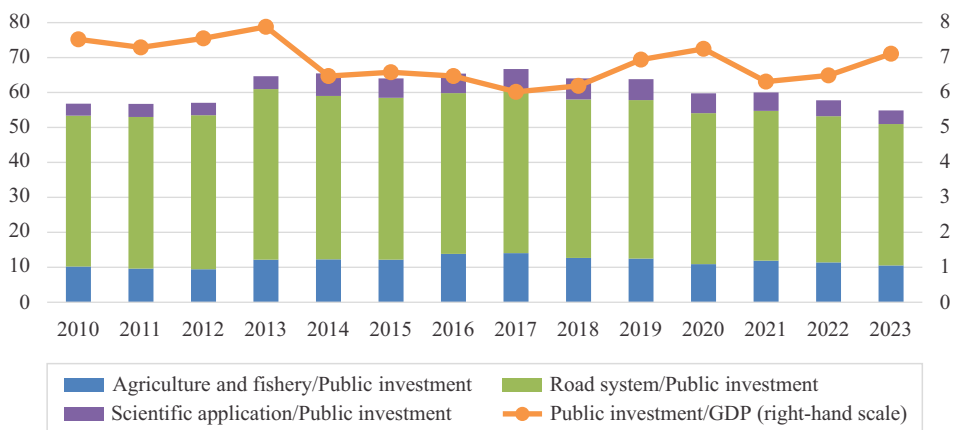


Fig. 1. Public investment in Vietnam (%).

Source: General Statistics Office of Vietnam.

uneven development across regions, and low technical standards, resulting in frequent repairs and severe deterioration of many roads. Additionally, transportation infrastructure is heavily affected by climate change, including saline intrusion in coastal areas, flooding, and landslides in northern provinces, as well as persistent flooding in southern provinces (Le et al., 2023). These issues have considerably impacted economic development. According to the World Bank (2022), Vietnam needs to invest an additional \$1.5 million per kilometer to mitigate the impacts of climate change and upgrade 20 sections of national highways to climate-resilient standards. This requires approximately \$153 million in new investments but is expected to yield benefits ranging from \$651 million to \$3.66 billion over 35 years.

Public investment in science and technology (S&T) is a critical expenditure for the government of any nation. Investing in S&T is one of the fundamental strategies to guide underdeveloped countries toward becoming developed economies, fostering the creation of core technologies, and reducing dependence on foreign resources (Klingler-Vidra and Wade, 2020). However, Vietnam faces prominent challenges in implementing public investment in this field, primarily due to insufficient funding. Between 2010 and 2023, Vietnam's national expenditure on S&T was only about 0.8%–1% of GDP¹ (GSO, 2024), whereas Resolution No. 20-NQ/TW stipulates a target of over 2% of GDP. Additionally, the objectives outlined in Vietnam's S&T and innovation development strategies are often misaligned, hindered by inconsistent and incomplete policy mechanisms. Delays in revising or issuing policy documents have created obstacles to implementing S&T development. For instance, there are no regulations on the auctioning of assets resulting from research, intellectual property, or mechanisms to protect the rights of public research organizations that own intellectual property such as patents, copyrights, and trademarks (Nguyen et al., 2021). Furthermore, there is no established framework for determining the number of S&T tasks and the total budget for each national-level program. This has led to an increase in both the number and cost of science & technology tasks over the years, resulting in scattered allocation of the S&T operational budget, which is often distributed multiple times a year, adversely affecting the progress of these tasks (Van Doan, 2023). The operational mechanisms of funds in the science & technology sector also exhibit several limitations, which prevent them from fully realizing their mission and vision. For instance, the National Science & Technology Development Fund, regulated under a specific mechanism by the government, still follows the general budget estimation guidelines issued annually by the Ministry of Science and Technology, treating it similarly to S&T tasks at the ministerial, provincial, or institutional levels. These challenges have hindered the effectiveness of public investment in science & technology and its role as a driver of economic development and improved quality of life for the population (Nguyen, 2024).

4.2. Identifying the crowding-in/out effect of public investment on private investment in Vietnam

To estimate the panel data model, neglecting the cross-sectional dependence (CSD) test in the data included in the research model can lead to biased results. The results of the CSD test, as suggested by Pesaran (2004), are presented in Table 2. As shown

¹ General statistical office of Vietnam. <https://www.nso.gov.vn/en/homepage/>

Table 2
Results of CSD test.

Variables	CD-test	<i>p</i> -value	Corr.	Abs (corr.)
PI	63.255	0.000	0.29	0.35
GDP	75.077	0.000	0.35	0.43
OP	69.825	0.000	0.32	0.37
CR	34.643	0.000	0.16	0.30
RE	5.536	0.000	0.03	0.18
LB	75.772	0.000	0.35	0.43
PU	15.889	0.000	0.07	0.19

Source: Authors' calculations.

Table 3
Synopsis of slope of homogeneity result.

H0: slope coefficient is homogenous			
Δ	<i>P</i> -stats	Δ adjusted	<i>P</i> -stats
2.708	0.000***	3.425	0.000***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

Table 4
Second generation unit root test.

Variables	CIPS		CADF	
	Level	1 st difference	Level	1 st difference
PI	-3.052***	-5.537***	-1.788	-2.665***
GDP	-4.080***	-5.687***	-2.075*	-3.295***
OP	-1.053	-3.104***	-1.874	-2.846***
CR	-3.125***	-4.848***	-2.242***	-2.783***
RE	-4.173***	-5.690***	-2.286***	-3.489***
LB	-3.712***	-5.637***	-2.543***	-3.863***
PU	-4.181***	-6.004***	-2.089**	-3.666***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

in Table 2, the null hypothesis of no CSD is rejected at the 1% level, indicating that the presence of CSD is confirmed for all the variables in the research model. Thus, the necessary condition has been met, and the subsequent steps can be carried out.

The results of the slope homogeneity test, as proposed by Pesaran and Yamagata (2008), are presented in Table 3. The results indicate significance at the 1% level, which means that the null hypothesis (slope homogeneity) is rejected for all variables.

Since the data included in the model exhibits CSD, conducting a first-generation panel unit root test would lead to inaccurate results. Therefore, this study employed a second-generation panel unit root test. We used the CIPS and CADF tests as proposed by Pesaran (2007), with the results presented in Table 4. As shown in Table 4, the OP variable is not stationary at the level, but after taking the first difference, all variables become stationary at the first difference level. This satisfies the condition to proceed with the subsequent steps.

To test for the existence of a long-term relationship between the independent and dependent variables in the research model, the author employed the Kao (1999) and Pedroni (1999) cointegration tests.

Table 5
Results of Pedroni and Kao panel cointegration.

Estimates	Statistic	<i>p</i> -value
Pedroni test for cointegration		
Modified Phillips–Perron test	7.1224	0.0000
Phillips–Perron test	–12.3857	0.0000
Augmented Dickey–Fuller test	–12.9173	0.0000
Kao test for cointegration		
Modified Dickey–Fuller test	–6.2797	0.0000
Dickey–Fuller test	–11.7093	0.0000
Augmented Dickey–Fuller test	–3.1351	0.0000
Unadjusted modified Dickey–Fuller test	–36.8605	0.0000
Unadjusted Dickey–Fuller test	–23.5662	0.0000

Source: Authors' calculations.

Table 6
Long-term estimation results.

Variables	CS-ARDL (short-run)	Long run estimates		
		CS-ARDL	FMOLS	DOLS
ECT (-1)	–0.9213***	–	–	–
GDP	0.0585***	0.0707***	0.0897***	0.1086***
OP	0.3328***	0.3536***	0.2994***	0.2371***
CR	0.0438*	0.0616	0.0848***	0.0624***
RE	–0.0055	–0.0083	–0.0433***	–0.0313
LB	0.0177***	0.01888***	0.0257***	0.0426***
PU	0.0750***	0.0721**	0.1964***	0.2268***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' calculations.

As shown in Table 5, the statistical values are all below 1%, indicating the existence of a cointegration relationship and a long-term relationship between the independent and dependent variables in the research model.

The long-term estimation results and the analysis of the relationship between the dependent and independent variables using the CS-ARDL model are presented in Table 6. Additionally, to assess the robustness of the long-term relationship between the independent and dependent variables, the study employed the FMOLS and DOLS models.

From the results of the CS-ARDL model, it can be observed that public investment has a positive effect on private investment in both the short term ($\beta = 0.075$) and the long term ($\beta = 0.0721$). This means that public investment has a crowding-in effect on private investment. This highlights the significant role of public investment in attracting and efficiently utilizing private investment capital (Nguyen and Phong, 2018; Anh et al., 2021). To provide robust evidence of the long-term impact of public investment on private investment, the results from the FMOLS and DOLS models also show that public investment positively affects private investment, with coefficients of $\beta = 0.1964$ and $\beta = 0.2268$, respectively. These results reflect the considerable efforts by the Vietnamese government in selecting and managing projects, and ensuring that budget resources are used most effectively, thereby attracting private investment, promoting economic development, and improving the living standards of the Vietnamese people (Nguyen et al., 2024; Phuong, 2020). This is also clearly demonstrated by Vietnam's GDP growth in recent years, which has consistently increased. Even

during the COVID-19 pandemic, when many economies around the world experienced negative growth, Vietnam maintained positive growth: 2.1% in 2021, 8.0% in 2022, and 5.05% in 2023 (GSO, 2024). The Vietnamese government has made significant efforts to both control the pandemic and develop the economy, allowing Vietnam to quickly suppress the pandemic and recover economically (Diem, 2024; Nguyen and Nguyen, 2021). These results also support the Keynesian perspective that public investment can crowd in private investment, particularly when directed toward productive sectors. However, as emphasized by Kurz (1985) and Mariolis and Ntemiroglou (2023), the impact of public investment depends heavily on its physical composition—whether it is allocated to infrastructure, education, or less productive sectors—and exhibits non-monotonic behavior. In Vietnam's case, the crowding-in effect likely stems from efficient allocations to infrastructure, transport, and irrigation that improve business conditions. Yet, this also suggests that beyond a certain point or when allocated inefficiently, public investment could reverse this effect, reinforcing the non-linear nature identified in our threshold model.

Moreover, the Vietnamese government has established a stable financial market, encouraging domestic and foreign banks and financial institutions to invest heavily in private enterprises. This has significantly contributed to reducing lending interest rates, which is a crucial source of capital for businesses (Nguyen and Phong, 2018; Le et al., 2023; Van Bon, 2019). During periods of economic instability, the State Bank has implemented decisive measures to reduce lending interest rates, such as imposing interest rate ceilings, controlling inflation, and strictly handling cases of interest rate violations. As a result, private enterprises, especially small and medium-sized ones, have been able to access bank capital with preferential interest rates. Even during the COVID-19 outbreak, Vietnam implemented interest rate support and restructured loans to help private enterprises quickly recover their production (Nguyen and Phong, 2018; Vu, 2024).

To encourage the development of private enterprises, Vietnam has continuously improved administrative procedures. The government has decisively eliminated and replaced outdated procedures with new ones. Local governments also frequently hold forums and conferences to listen to the opinions of businesses (Kim and Le, 2021; Ha and Fujiwara, 2015). This serves as a basis for quickly addressing obstacles in procedures such as land, taxes, and production certificates. In the era of globalization, Vietnam has actively participated in free trade agreements, providing a good opportunity for Vietnamese goods to access large international markets. Vietnam has also organized many trade exhibitions, connecting domestic producers with foreign enterprises to boost exports. Notably, Vietnam pays close attention to consumer preferences and international standards to meet product requirements (Anh et al., 2021; Phuong, 2020; Su and Bui, 2017).

4.3. Public investment in Russia and valuable lessons for Vietnam

In recent years, Russian agriculture has achieved remarkable accomplishments, not only ensuring food security but also contributing significantly to exports. In 2010, the export value of agricultural products was \$8.1 billion, which increased to \$43.5 billion by 2023 (Rosstat, 2023). These achievements are attributed to government policies implemented through targeted programs aimed at increasing production volume. Approximately 40% to 50% of public investment in agriculture

has been allocated to production expansion, particularly in supporting small-scale farmers to ensure self-sufficiency in food and generate surpluses for market sales. Public investments in agriculture primarily focus on providing farmers with essential inputs such as fertilizers, seeds, and production fuels. Small-scale farmers, often facing financial constraints for production expansion, receive approximately 15% to 30% of public investment through medium- and long-term credit programs (Shik, 2020). Furthermore, agriculture in Russia not only ensures food security but has also become a critical objective in export activities. Therefore, the government actively supports services such as phytosanitary and veterinary inspections to meet the growing quality requirements for export products. Additionally, around 10% of total agricultural spending is dedicated to funding research and development in agricultural products, leading to improvements in both the quantity and quality of crop and livestock varieties. Consequently, the agricultural sector has successfully met domestic food demands while contributing increasingly to export growth. In a study by Gordeev et al. (2022), it was highlighted that Russia's geographical location makes it highly sensitive to climate change, significantly impacting its agriculture sector. Global warming trends have affected crop yields and harvest volumes. However, milder winters, especially in regions such as Urals, Volga, and Siberia, have positively influenced agricultural development. On the contrary, challenges such as droughts, widespread diseases, and extensive flooding have posed significant threats, necessitating responsive measures. In recent years, the Russian government has allocated substantial public investment to scientific research aimed at enhancing agricultural product quality. Investments have also been made in agricultural infrastructure, including irrigation systems for the rainy season and measures to combat disease outbreaks. Moreover, new crop varieties have been developed to address declining protein content in cereal grains. Thus, public investment plays a vital role in shaping and sustaining Russia's agriculture for long-term development.

Transportation is one of the most important sectors for the economy of any country. It also requires a significant amount of public investment. For the Russian economy, the reconstruction and modernization of the transportation sector is essential in all major cities across Russia in order to create a transportation network that links regions, promotes domestic economic growth, and reduces dependence on foreign markets (Agamamedova et al., 2023). Therefore, public investment in the road transportation system always accounts for a high proportion (Fig. 2). By 2022, following the conflict between Russia and Ukraine, the Russian economy faced numerous challenges, including sanctions from many countries (Nguyen and Khominich, 2024). This also negatively impacted the development of Russia's transportation infrastructure, such as imposing bans on the import of specialized equipment for building transportation routes, repairing and purchasing vehicles, particularly technologies used for modernizing transportation and reducing the negative effects of climate change on the quality of infrastructure (Porfiriev et al., 2023). According to a study by Badina et al. (2024), the maximum cost to replace and repair the entire railway system across Russia is estimated at 11 trillion rubles, equivalent to 8.4% of the GDP, due to the impacts of climate change such as flooding, geological changes, and weather events. Therefore, during the approval and assessment process of infrastructure investment projects, particularly in transportation, it is necessary to research and forecast natural risks, then develop construction plans that are aligned with the actual conditions in order to avoid significant damage. In addition

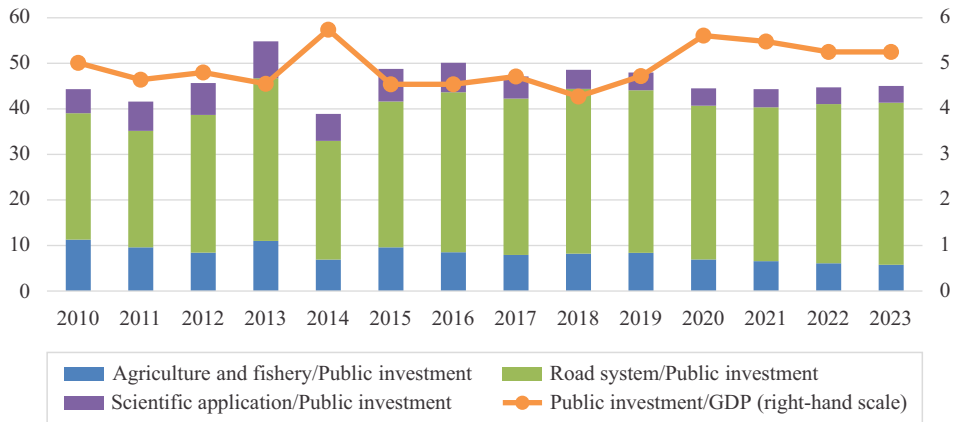


Fig. 2. Public investment in Russia (%).

Source: Authors' calculations using data from the Federal State Statistics Service of Russia.

to the negative impacts that the transportation sector is facing, this also presents an opportunity for Russia to improve technology and develop domestic production. Alongside railway lines, road transport networks are also greatly affected by both the quality and cost of construction. A study by Porfiriev et al. (2023) concluded that through public investment, new technologies have been developed and adapted to better suit natural conditions, thus reducing negative impacts on the quality of these road networks. Moreover, this investment has significantly contributed to reducing the frequency of traffic accidents. However, with the increasing costs, this remains a considerable burden for certain regions in Russia. Despite this, research also indicates that for every ruble invested, there is a return of 3.1 rubles in economic effectiveness. Therefore, it is evident that the role of public investment in Russia's transportation sector is crucial, not only in supporting economic development and advancing new technologies amid the sanctions but also in helping reduce the severity of traffic accidents, as well as the number and volume of repair work.

Science and technology is a field that requires significant investment and faces many risks, but it has a profound impact on the lives of people as well as the development of the economy. Therefore, it is also a sector that demands substantial public investment. In recent years, the Russian Federation has made many achievements in scientific research but has not yet reached the expected outcomes: in 2020, the number of patents did not rank in the top 10 globally, with 30,000 patents, while the USA had 496,000 patents and China had 1.441 million patents. Additionally, the proportion of high-tech exports remains low, which is a relatively significant issue in applying scientific research results to production and business (Klepach et al., 2022). The explanation for this situation is that the funding for science and technology is not sufficiently high. Moreover, scientific research products have not been widely applied, and many research products are not put into practice. Thus, it has not been possible to turn research into commercial products, as companies in Russia are focused on producing products in the raw materials, energy, and basic materials sectors, where technology is rarely applied to production. The second reason put forward is the lack of coherence in science and technology development policies. The Russian Federation follows a science and technology development model based on universities and the development of venture capital funds to fi-

nance these projects. In reality, scientific research is still concentrated in scientific organizations, including state research centers. This is also a reason for the low research efficiency (Ilina et al., 2019). Furthermore, the list of priority areas for science and technology investment is not frequently updated, and there are no specific indicators for funding sources to implement these priority projects. The latest list was published in 2024, and the previous one was from 2015.

After economic crises, public investment serves as a crucial tool, acting as leverage to help nations quickly recover their economies and attract substantial private investment. However, over-reliance on public investment or inefficient use of public investment can have negative effects on the intended objectives. According to Melnikov (2021), the Russian economy, with its strong budgetary resources, invested heavily in infrastructure to improve the quality of life for citizens and attract private investment. However, numerous issues arose during the implementation process, including the negative impact of public investment on economic growth and private investment attraction. This can be explained by the fact that the level of public investment exceeded the productive capacity of the economy. Moreover, many public investment projects were driven by political and social welfare objectives with little focus on profitability, which means this capital did not directly contribute to economic growth. Vlasov and Sinyakov (2020) indicate that if policymakers do not accurately and specifically calculate the amount of public investment injected into the market, it can lead to inflation, drive up interest rates in the money market, and reduce the ability to maintain price stability in the economy. These are significant causes of the crowding out of private investment in the economy.

Further research into the inefficiency of public investment in Russia by Belov (2018) revealed that public investments funded by the federal budget negatively impacted economic development and the attraction of private investment, while projects funded by local budgets had the opposite effect. This was due to the large scale of these projects, with poor management practices such as project selection, project studies, and project implementation leading to increased investment costs and decreased project efficiency (Kramin and Aleev, 2019). Additionally, project oversight must pay close attention to climate change issues, as public investment projects, often infrastructure-related, are significantly affected by climate change. If not carefully considered, with appropriate project selection and risk prevention plans, these projects can quickly deteriorate, resulting in a significant waste of state budget resources (Melnikov and Furmanov, 2020).

Zakharov (2019) noted that the corruption rate in Russia is relatively high, which negatively affects public investment projects. Corruption not only drives up public investment costs but also severely impacts the quality of infrastructure projects. This, in turn, has adverse effects on private investment attraction and economic development. Therefore, to improve the efficiency of public investment, it is crucial to implement positive measures for managing this capital, such as tightening administrative management, especially at the local level. Moreover, changing the form of public investment, such as focusing on key project programs and public-private partnerships, is necessary. The impact of each project on the economy and society should be clearly defined to ensure that budget resources are allocated appropriately and where they are most needed. This can enhance the effectiveness of public investment projects, stimulate private investment capital, and enable private investors to use capital more efficiently (Knyazeva and Samkov, 2023; Myakshin et al., 2023).

After the conflict between Russia and Ukraine, the Russian economy has faced significant pressures in general and on public investment in particular. Russia is currently subject to numerous economic sanctions from various countries worldwide, which affect not only GDP growth but also the structure of its economy.

To contribute to combating climate change and mitigating potential damages of up to 2% of GDP and 45% of total output in certain regions (Korppoo and Alisson, 2023), Russia enacted Law No. 296-FZ dated 02.07.2021 “On Limiting Greenhouse Gas Emissions.” This has a substantial impact on the economic structure, as 77% of CO₂ emissions come from the energy sector (Korppoo and Alisson, 2023). Therefore, to achieve these goals, Russia must make significant public investments in low-carbon nuclear and hydroelectric plants to replace conventional thermal power plants (Ministry of Economic Development of the Russian Federation, 2023).

Additionally, Russian industries, such as cement and steel production, contribute heavily to CO₂ emissions. Consequently, the Russian government needs to allocate substantial public investment resources to transition towards a greener economic structure and support the adoption of new energy sources (Korppoo and Alisson, 2023; Nguyen and Khominich, 2023). Another major challenge for the Russian economy is the need to reduce its dependence on crude oil exports, as sanctions and declining global demand—driven by climate change and reduced fossil fuel use—exert pressure (Javeline et al., 2024). In response, Russia is focusing on public investment in infrastructure to attract green investment projects, which presents an opportunity for the country to successfully achieve its commitment to reach carbon neutrality no later than 2060.

Thus, it is clear that, in the current context, public investment in both Russia and Vietnam shares many similarities, such as the need for strong investment in science and technology to reduce dependence on foreign countries. Both countries aim to gradually transform infrastructure to attract green investment projects, combat climate change, and reduce reliance on fossil fuels. Public investment projects must be comprehensively studied, particularly to minimize damage caused by natural disasters, ensure food security, and increasingly contribute to exports.

From this, it can be observed that although public investment in Russia is crowding out private investment due to excessive public spending and inefficient management, Russia faces the significant challenge of needing to strengthen public investment to restructure its economy in a manner more suited to the current context, enhance domestic potential, and reduce dependence on foreign countries. This will serve as a valuable lesson for Vietnam’s economy.

4.4. Public investment threshold to avoid crowding out private investment for Vietnam

After the economic crisis caused by the COVID-19 pandemic, Vietnam used public investment as a tool to stimulate economic growth. However, it is crucial to determine the necessary amount of investment to avoid the crowding out of private investment. The results are presented in Table 7.

According to Table 7, we can reject the null hypothesis of the threshold effect at the 1% level of significance. This indicates a non-linear relationship between private investment and public investment. The study’s results on the threshold effect of public investment on private investment, where public investment is the threshold variable,

Table 7

The results of the public investment ratio threshold.

Dynamic panel threshold	Lower regime	Higher regime
Lag of PI	-0.4747**	0.5969***
GDP	-0.8888***	1.1850***
OP	0.5537	-1.2090**
CR	0.3010***	-0.3709***
RE	-0.0202	0.0142
LB	1.6502***	-1.1478***
PU	1.6634***	-2.0665***
Constant		1.5220***
Threshold	8.532***	
Bootstrap linearity test	0.001	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The stata command “xthenreg” is used to estimate the results. The value of grid point, trim rate and bootstrapping are set as 100, 0.3, and 100, respectively.

Source: Authors' calculations.

show that the coefficient of public investment below the threshold is 1.6634, with statistical significance at the 1% level. Below the threshold, a 1-pp increase in PU is associated with +1.6634 pp in PI ($p < 0.01$), while above the threshold it is associated with -2.0665 pp ($p < 0.01$). The threshold value is 8.532 at a statistical significance level below 1%, meaning that if the public investment/GDP ratio exceeds 8.532%, it will lead to a crowding-out effect on private investment. This finding aligns with existing theories, which suggest that if public investment exceeds the productive capacity of the economy, it consumes too many input factors, leading to increased prices and higher market interest rates, which in turn result in public investment negatively impacting private investment. This is a crucial figure in managing public investment before making investment decisions, as well as in ensuring effective investment management to avoid waste of state budget resources.

4.5. Limitations in the public investment management system in Vietnam

Climate change adaptation has not been fully considered in public investment decisions. Vietnam is a country located in the tropical monsoon climate zone, heavily impacted by climate change (Le and Pham, 2023). Primarily, higher temperatures, rising sea levels, and increased extreme weather variability have disrupted economic activities and weakened growth. Preliminary calculations indicate that Vietnam lost \$10 billion in 2020, equivalent to 3.2% of its GDP, due to the impacts of climate variability. Without appropriate adaptation and mitigation measures, it is estimated that climate change could cause Vietnam to lose approximately 12% to 14.5% of its GDP annually by 2050 and push one million people into extreme poverty by 2030 (World Bank, 2022). The Vietnamese government has intensified investments to address the damages caused by climate change (CC).

From Table 8, it can be seen that there is a unidirectional causal relationship running from climate-related damages to public investment, without the reverse being true. This indicates that environmental shocks caused by a changing climate influence the volume of public investment. The result reflects Vietnam's current situation, where fiscal resources are allocated to repair and construct infrastructure in response to such events. Nevertheless, only a few projects are resilient enough to withstand severe climatic impacts. A further challenge is that adaptation has not yet

Table 8

Results of Dumitrescu & Hurlin causality test.

Null hypothesis	W-bar	Z-bar	p-value
CC does not Granger-cause PU	4.385	5.385	0.0000
PU does not Granger-cause CC	3.564	3.302	0.2360

Note: The Dumitrescu Hurlin test is estimated with 1 lag and Zbar-statistics.

Source: Authors' calculations.

been fully integrated into the overall financial strategy or into the selection of priority projects. The high-level policy commitments of the Vietnamese Prime Minister to net-zero emissions by 2050, the green growth strategy to 2030 with a vision to 2050, and related action plans are not yet accompanied by systematic forecasts from the Ministry of Finance or the Ministry of Planning and Investment regarding the fiscal and investment impacts of these commitments and policies. As a result, the number of green infrastructure and climate-resilient projects, although initially included in the budget, remains limited, despite initial budget allocations for some additional measures to make projects more resilient and sustainable, along with contingency funds for unforeseen events, including climate-related events (Ha and Fujiwara, 2015; Tuan and Dung, 2023). However, localities are still not prepared to assess and mitigate risks related to infrastructure and transitional risks and to adapt to climate change impacts on assets and projects due to a lack of policies, guidelines, and specific procedures. The lack of information on asset value and risk exposure will increase the insurance costs of local assets. To address some of these challenges, it is necessary to digitize key public asset and financial management functions while engaging more in proactive risk management (Van Bon, 2019; Le et al., 2023).

Challenges still persist throughout the entire cycle of public investment management, from project preparation to implementation, monitoring and evaluation, and asset management post-construction. These issues are interconnected. Weaknesses in planning and appraisal lead to poor project inputs, which affect implementation and subsequent adjustments, resulting in cost overruns and delays. Similarly, difficulties during project implementation often indicate problems that originated during the planning and appraisal stages.

Project preparation (Project selection). A major obstacle here is the lack of standardized guidelines for evidence-based decision-making support. Group B projects, considered large projects in most provinces, do not require a feasibility study report. Except for projects using official development assistance (ODA) funds, feasibility studies are often not made public. Project budget estimates are often inaccurate due to low technical and cost standards, and land clearance and resettlement costs and timelines are typically underestimated, leading to adjustments and delays (Su and Bui, 2017; Anh et al., 2021). These chronic issues stem from the lack of adequate budget and time for producing high-quality feasibility studies with reliable budget estimates, as the project proposal stage must align with the five-year cycle of medium-term public investment planning. However, project owners are often reluctant to adjust the total project investment at the feasibility study stage, as any changes would require reverting to the feasibility study stage (Kim and Le, 2021). Moreover, lifecycle costs, including both investment and operational costs, are not estimated during the feasibility study phase, leading to a lack of funds for operation and maintenance for most public investment projects (Nguyen et al., 2024).

Project implementation. Complex procedures affect the progress of project implementation and disbursement, as well as the approval of necessary project adjustments. Although budgets are allocated at the beginning of the year, most projects take up to five months to complete detailed activities and bidding plans before starting implementation. The time and cost of land clearance and resettlement processes also impact project execution (Phuong, 2020; Vu, 2024). The benefits of competitive bidding, although considered the default method under the Bidding Law, are not fully realized due to the relatively frequent use of direct contracting. The monitoring systems for project implementation are scattered and somewhat passive, leading to an inability to timely assess and fundamentally adjust projects when necessary. There is currently no mechanism for central and local authorities to systematically identify projects at risk of non-completion and implement timely corrective measures. Information systems for managing project commitments are essential for monitoring and ensuring funds for ongoing projects, but these systems are not yet fully developed (Ha and Fujiwara, 2015; Nguyen et al., 2024).

Monitoring, evaluation, and post-project review. The project database is a crucial factor for the effective operation of monitoring and evaluation systems and needs further improvement. The State Budget Investment Management Information System, developed by the Ministry of Planning and Investment in 2017, has collected information on investment capital allocation. However, the data is still incomplete, compliance levels for updating data by project owners are low, and data sharing between government agencies is limited. The percentages of projects monitored, inspected, and evaluated through the system were only 47.3%, 25.6%, and 39.2%, respectively, in 2022 (Nguyen et al., 2024). The system has not yet been integrated with the budget management and treasury systems to exchange necessary information such as commitment of expenditures, disbursement, and implementation progress to form the basis for necessary remedial measures. Some localities have invested in their own systems to monitor projects, leading to fragmented data. Public investment data is often not publicly disclosed, which does not actively support monitoring and evaluation efforts by stakeholders (An, 2024; Tuan and Dung, 2023; Le et al., 2023). Although there is now a legal basis for post-project evaluation, such evaluations are rarely carried out, except for ODA projects, and these evaluations often do not adequately reflect the lessons learned (Diem, 2024; Van Bon, 2019).

Public asset management. A comprehensive legal framework for the accounting and reporting of public assets is still lacking, and the asset database has not been integrated or updated, limiting decision-making capacity for new investments, operations, and maintenance, or policy-making based on assets for all infrastructure projects at both central and local levels (Vu, 2024). Although the Law on Public Asset Management clearly stipulates infrastructure assets, only guidelines for accounting and managing road, clean water, and irrigation infrastructure have been issued. These guidelines have also not been consistently applied, reducing the accuracy of reports related to asset values. The dual budget system, in which the Ministry of Finance manages recurrent expenditures while the Ministry of Planning and Investment manages investment expenditures, also creates challenges in ensuring funds for operations and maintenance (Tuan and Dung, 2023).

Spatial and financial planning and public investment are not linked. In the context of strong decentralization, the planning and budgeting system faces difficulties in coordinating top-down strategic priorities with bottom-up project identifica-

tion by provinces (Diem, 2024; Vu, 2024). The Planning Law introduced in 2019 laid the foundation for a shift in approach towards integrated spatial planning at the national and regional levels. The National Comprehensive Development Plan for 2030 and Vision for 2050 focus on supporting four dynamic regions and six socio-economic regions. This integrated spatial development approach will require a consistent approach to linked investments and regional integration (Kien and Nguyen, 2023). However, this approach is currently facing challenges in its implementation. Many plans, including the 10-year national, regional, sectoral, and provincial plans, are poorly connected to the related five-year Medium-Term Public Investment Plan. Investment projects carried out across multiple provinces play a critical role in strengthening interprovincial connectivity, addressing environmental and climate change impacts, and creating synergy between public and private investment. However, there are currently some obstacles to implementing such connectivity investment projects, both vertically and horizontally, between different levels (Ha and Fujiwara, 2015; Le et al., 2023).

Legal barriers to connectivity investment projects. The State Budget Law (2015) does not yet provide for vertical and horizontal budget coordination mechanisms. In terms of vertical coordination, the law generally assigns projects of nationwide and interprovincial scope to the central budget through ministries. However, the interprovincial nature of investments and the responsibilities of each party have not been clearly defined (Diem, 2014). The State Budget Law also provides a general description of the responsibility for providing infrastructure services but has not fully considered the resources and incentive mechanisms needed to ensure these services are provided. This leads to underinvestment in infrastructure networks, especially interprovincial infrastructure. In terms of horizontal coordination, the State Budget Law does not allow for budget coordination between localities, both spatially and sectorally (Kim and Le, 2021).

Institutional challenges in coordination. Vietnam has pursued several regional investment coordination methods since the early 2000s, but none have yielded the desired results. From 2002 to 2020, through several efforts, regional steering committees were established for specific regions, such as the Southeast Region (2002), Central Highlands (2002), Northwest (2004), and more recently, the Mekong Delta Regional Coordination Council (2020). However, experience shows that regional coordination councils alone cannot resolve existing challenges if legal, financial, and other barriers are not resolved to realize the need for regional investment (Diem, 2024; Kim and Le, 2021).

Lack of effective mechanisms to promote financial and investment linkages. The public investment modality mentioned in the Public Investment Law (2019) has not yet been fully operationalized and effectively implemented in practice. This modality can connect parties both vertically and horizontally. For domestic resources, the only official vertical connection mechanism currently implemented is through national target programs. Currently, there is much debate about the appropriateness of the scale and institutional structure for better connecting resources to achieve higher target results. For external resources, managed through the Public Debt Management Law (2017), the financial co-contribution mechanism (a combination of grants and re-lending) was introduced in 2017. Localities are divided into five groups depending on their fiscal capacity, calculated by their dependence on central budget support, to determine different financial contribution

and re-lending rates. However, programmatic mechanisms to connect the central budget with the budgets of multiple localities have been discontinued in recent years due to concerns about the complexity of such projects.

Challenges in interprovincial and interregional development. These challenges are increasingly frequent and severe, requiring coordinated action between different levels of government. Issues such as climate change adaptation and mitigation, groundwater exploitation, surface and groundwater pollution, waste and air pollution, aging water infrastructure, conflicts over water sharing, and increasing drought and flooding are becoming more common (Nguyen and Nguyen, 2021; Kim and Le, 2021). In many cases, industrial plants, plastic waste, and dredged materials in upstream provinces are polluting water flows, creating severe negative externalities for downstream provinces, but efforts to address these issues cannot resolve the problems caused by the polluting entities. For example, in the Central Coastal Region, Da Nang City has sent numerous petitions to Quang Nam Province and the Prime Minister regarding issues related to changes in water flow, exacerbating flooding during heavy rains in upstream areas, and causing drought in downstream areas during the dry season. Despite the high costs of managing flood and drought risks, the current public investment management system and intergovernmental fiscal relations do not allow for these considerations and also they fail to prioritize the implementation of such inter-regional and interprovincial investment projects (Le et al., 2023; Vu, 2024).

General limitations in project appraisal methods. These limitations mean that risks and climate change adaptation have not been adequately addressed. The inadequacies in project appraisal, specifically the lack of a systematic methodology such as social cost-benefit analysis, mean there is no methodological basis for assessing different adaptation options for addressing identified climate change impacts. Appraisal for large projects requires an environmental impact assessment (Kim and Le, 2021). In essence, related to climate change forecasting and adaptation, the appraisal process needs to consider both the impact of the project and the project itself (Kien and Nguyen, 2023). Although the Construction Law and its subordinate regulations stipulate procedures for projects with construction components, including the requirement to consider climate change risks and adaptation, there are no specific requirements and guidelines on how to consider and assess climate change risks from the project preparation stage, such as during the preparation and appraisal of feasibility study reports, which is a more effective time to develop, analyze, and synthesize adaptation options (Canh and Phong, 2018; Le et al., 2023).

5. Conclusion and policy implications

The objective of this article is to examine the impact of public investment on private investment. Specifically, we have investigated the existence of crowding-in/out effects in Vietnam. Our contribution to the existing literature lies in providing robust evidence of this relationship. By applying the CS-ARDL model and conducting a robust check using the FMOLS and DOLS models, we found that public investment has a crowding-in effect on private investment. This effect is positively influenced by stable GDP growth, which has enabled private enterprises to achieve higher profits and accumulate more capital, thereby boosting production and business activities. Additionally, the government's positive contribution

to expanding international markets and facilitating the export of goods to new markets has resulted in high economic efficiency. The government encourages domestic and foreign banks and financial institutions to invest in private investment activities under state supervision, allowing enterprises to access low-interest loans. Furthermore, to better meet the practical demands in the context of global integration, Vietnam has been vigorously implementing administrative reforms to create the best conditions for businesses to operate and enhance investment efficiency. Moreover, the government has a clear strategy for preparing the labor force through training in skills and education, as well as developing projects such as housing for workers in industrial zones, public utility areas, and schools for the children of workers in industrial zones. This has attracted a large number of high-quality and affordable laborers to meet the needs of private enterprises.

After identifying the crowding-in effect of public investment on private investment, the study examined valuable lessons from the Russian economy regarding the causes of crowding out public investment on private investment. Two main causes were identified: first, excessive public investment, and second, inefficient public investment. Based on these profound lessons from the Russian economy, the study employed the dynamic panel threshold model to determine that the maximum public investment/GDP ratio is 8.532%. If this threshold is exceeded, public investment will crowd out private investment. This figure is crucial for public investment managers to select investment capital as well as allocate and choose public investment projects appropriately.

The results indicate that not only the scale of public investment matters, but its composition is also of critical importance. According to Keynesian theory, the physical composition of government spending—such as whether funds are directed toward infrastructure, education, or other productive sectors—plays a decisive role in determining whether public investment stimulates or inhibits private investment. Furthermore, the relationship between public and private investment is not always linear. As shown in our threshold analysis, while public investment below a certain level can enhance private sector activity, excessive or inefficient spending may produce the opposite effect. This non-monotonic dynamic highlights the need for strategic allocation: focusing resources on sectors that yield high social and economic returns is essential to maximize the crowding-in effect and to avoid unintended negative consequences. Therefore, the Vietnamese government should implement the following measures.

Firstly, it is necessary to improve project planning and appraisal, as projects with low-quality inputs often require adjustments, leading to cost overruns and delays. Recommended reforms include allocating more time and budget for preparing pre-feasibility study reports and updating medium-term public investment plans. Cost norms, unit prices, and land prices should be regularly updated to align with market conditions, ensuring that cost estimates are realistic. Additionally, management documents should provide specific guidance to improve the quality of pre-feasibility study reports, aiming to apply social cost-benefit analysis and supplementary tools to clarify the total estimated lifetime costs of projects from the proposal stage. To enhance Vietnam's climate change resilience, early screening for climate change factors should be required from the investment planning stage, and relevant adaptation measures should be assessed in both the pre-feasibility and feasibility study reports of high-risk projects.

Secondly, project implementation, monitoring, and evaluation need to be strengthened to ensure that investment expenditure becomes effective infrastructure once resources are allocated. Separating land clearance and resettlement from investment projects can help expedite implementation, especially for large projects. Decisions to adjust or terminate projects in practice should be based on a systematic mechanism for central and local authorities to identify projects at risk of being uncompleted, which can be facilitated through streamlined procedures. Satellite data and global positioning systems can be utilized for more accurate and timely analysis and decision-making. Moreover, the scope and depth of post-project evaluations should be enhanced, at least for large and medium-scale projects.

Thirdly, public asset management needs to be strengthened to improve the efficiency of related revenue and expenditure measures. Fundamental steps include establishing a database of all infrastructure assets, including their value, and deploying technology applications and data analysis to support budget allocation decisions for operation, maintenance, and new investments. Gradual reforms in accounting, valuation, and reporting of infrastructure assets are required to adopt more accurate asset valuation methods and better reflect depreciation and wear.

Fourthly, budgeting should be strategic and program-based. This involves improving the classification and presentation of the budget structure and enhancing the methods of public investment as stipulated in the Public Investment Law to support more effective budget orientation, such as regional development, green transformation, and climate change resilience.

Fifthly, investment management institutions and budget relations among government levels need to be modernized. The mechanisms for revenue-sharing and balancing principles should be updated to better balance the needs of the central government and local authorities, including provinces that are national growth drivers as well as poorer provinces. Legal constraints in the State Budget Law need to be removed to facilitate inter-budgetary investment, thereby enhancing the synergy effect of investments. The mandate of regional coordination councils should be expanded to identify investment priorities that align with regional planning. New mechanisms for capital pooling should be institutionalized based on transparently defined and scientifically formulated formulas, integrating considerations of financial mobilization capabilities from domestic and foreign sources within an overall framework.

Lastly, fiscal mechanisms and other incentives should be enacted to facilitate green investment actions and climate change adaptation in the relationships between government levels, such as supplementary budgets or ecosystem service payment contracts.

Despite the results achieved, the study still has gaps that need to be addressed in future research, such as evaluating the impact of corruption and climate change on public investment projects. These are important factors in understanding the role of public investment in attracting and effectively utilizing private investment capital in the future.

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