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RESEARCH ARTICLE

Is there a nonlinear relationship between public investment and private investment? Evidence from 21 Organization for Economic Cooperation and Development countries

Sofia São Marcos[1] | **Sofia Vale**[2]

[1]Department of Economics, Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal

[2]Economics Department, Instituto Universitário de Lisboa (ISCTE-IUL), Business Research Unit (BRU-IUL), Lisbon, Portugal

Correspondence
Sofia Vale, Economics Department, ISCTE-IUL, Av. Forças Armadas, 1649-026, Lisbon, Portugal.
Email: sofia.vale@iscte-iul.pt

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Abstract

This paper studies the relationship between public investment and private investment in a sample of 21 Organization for Economic Cooperation and Development (OECD) countries between 2000 and 2019. Using panel data nonlinear threshold regression models, the empirical results show that there exist threshold levels for the share of public investment in private investment, the real Gross Domestic Product (GDP) growth rate and the real interest rate that affect the relationship between public and private investment. All estimates support a crowding-in effect of public investment on private investment. In terms of policy prescriptions, by increasing public investment, OECD governments can expect positive spillovers to private investment.

KEYWORDS

OECD, private investment, public investment, threshold model

1 | INTRODUCTION

Even if public investment is one of the cornerstones of development strategies in advanced economies, its impact on private investment remains controversial, authors concluding for positive and negative effects, the crowding-out versus crowding-in argument. The global financial crisis and the sovereign debt recession banned the use of public expenditures as a way to encourage economic recovery, until the COVID-19 crisis rehabilitated it as an answer to the ongoing downturn, mainly in the form of major public investments (Tandberg & Allen, 2020). To which extent can public investment stimulate private investment is again at stake.

Public investment has a positive effect on output, being a determinant factor of labour productivity (Aschauer, 1989a, 1989b). Estimations of the multiplier effect of public spending and public investment have been pointing to positive values but are not consensual regarding their range (Abiad et al., 2016; Ramey, 2019). Despite public investment being seen as capable of expanding demand and stimulating output, a strand of the literature sustains that this is done at the expense of private investment, the crowding-out effect (e.g., Cevik, 2020; Miyazaki, 2018; Mohanty, 2019; Saeed et al., 2006; Vanhoudt et al., 2000; Voss, 2002). The use of scarce resources by the government and competition for funding that increase interest rates have been highlighted as the main reason beyond its pernicious impact.

Private investment is highly volatile, responding to economic activity through an accelerator mechanism

(Serven & Solimano, 1992), fluctuating above Gross Domestic Product (GDP) along the stages of the business cycle, affecting employment and output. Finding policy measures to stimulate it is a concern of decision-makers. By promoting favourable conditions through the construction of infrastructures, public investment is decisive as one of such measures, instigating private investment activities, the crowding-in effects (e.g., Abiad et al., 2016; Akber et al., 2020; Andrade & Duarte, 2016; Argimón et al., 1997; Barbosa et al., 2016; Carrillo et al., 2018; Dreger & Reimers, 2016; Pereira & Andraz, 2003). Afore this disagreement several authors argue that the type of impact public investment has on private investment is sensitive to the countries or even the period under inspection, reporting found mixed evidence on these effects (e.g., Afonso & Aubyn, 2019; Afonso & St. Aubyn, 2009; Agnello et al., 2013; Atukeren, 2005; Bahal et al., 2018; Nguyen & Trinh, 2018; Xu & Yan, 2014).

Several explanations have been put forward in the literature for this lack of consensus. Scale effects indicate the volume of public investment possibly has a tipping point. However, economies need to have the absorptive capacity to convert the scaling-up of public investment into additional economic growth (Gurara et al., 2020; Presbitero, 2016). If conflicting results are the outcome of different levels of countries' development (e.g., Erden & Holcombe, 2005), the growth rate may exert a threshold effect on the relationship between public and private investment. In addition, the government spending multiplier seems to be higher for lower levels of the interest rate (e.g., Christiano et al., 2011). It is then plausible to assume a tipping point for the interest rate affecting this relationship.

The regimes may also be sensitive to the economic circumstances that characterize each moment, where the existence of unconventional monetary policies, designed to respond to countries' fiscal imbalances, may be likely to alter both the tipping points and the impact that public investment has on private investment.

So far, most studies have assumed the existence of a linear relationship between public investment and private investment. This study contributes to this controversy by analysing empirically the relationship between private investment and public investment for a set of 21 European countries from the Organization for Economic Cooperation and Development (OECD) over the period 2000 to 2019 relying on panel data threshold models. We apply both the Hansen (1999, 2000) approach where the regressors and the threshold variable are assumed to be exogenous and the Seo and Shin (2016) Generalized Method of Moments (GMM) model that accounts for endogenous regressors and a threshold variable. The link between public and private investment is particularly relevant for these economies that rely on fiscal policies to sustain their welfare states (Bergh et al., 2017) and are on the verge of triggering large public investment projects to counteract the impact of the Covid-19 crisis (Elgin et al., 2020). The empirical threshold model inspects whether public investment has a crowding-in or crowding-out effect on private investment depends on a tipping point from macroeconomic fundamentals, such as the ratio of public to private investment, the growth rate of output, or the interest rate. With this methodology, it is not necessary to impose a priori restrictions usually controlled through dummy variables or interaction terms. Instead, it is introduced flexibility in the estimations by capturing endogenously the possible threshold level. Further, the paper explores whether the introduction of the unconventional monetary policy (UMP) has altered the nonlinear relationships between public investment and private investment by estimating the models for two sub-periods, namely before and after the introduction of the UMP measures. Results from this paper indicate that there are nonlinearities in the relationship between public investment and private investment, the former having a crowding-in effect on the latter that changes in intensity with the detected regimes, implying a critical role for fiscal policies directed to major investments and to the specific macroeconomic context in which they are put into practice.

The remaining of the paper is structured as follows. Section 2 overviews the literature that has been underlying the relationship between private investment and public investment. Section 3 presents a statistical overview of the relationship between these two variables. The Section 4 describes the data and presents the empirical model to be used. Section 5 presents and discusses the main findings and section six concludes.

2 | LITERATURE REVIEW

Whether public spending directed towards investment benefits or harms private investment is still an ongoing discussion. For classical economists, the less the government intervenes in the economy the better the outcome. This is extensible to any form of public investment that could cause public deficit and the accumulation of public debt, harming economic growth (Cecchetti et al., 2011). Public investment compromises private investment by implying a search for funding that increases the interest rate in the short run and taxation in the long run (Afonso & Jalles, 2015; Furceri & Sousa, 2011). When goods, services and infrastructures bought by the public sector imply raising taxes to finance their acquisition, they hinder private investment through the reduction of

private savings (Saeed et al., 2006; Vanhoudt et al., 2000). If these purchases raise the demand for funds in capital markets, they increase the cost of loans through the payment of higher interest rates, discouraging firms from investing and reducing the availability of financial resources (Barro, 1989).

Crowding-out effects of public investment on private investment have been confirmed in different macroeconomic contexts. In a long-run analysis of the United States and Canada, Voss (2002) found innovations in public investment undermining private investment, concluding that public capital and private capital are not complementary in these countries. The same result was found for the Fiji Islands by Narayan (2004), who attributed it to political instability and a focus on unproductive investment. Dash (2016) reported crowding-out effects in India, concluding that investment in infrastructures can promote private investment if the quality of the infrastructure is guaranteed and the financing of infrastructure construction does not condition the availability of bank credit or lending rates.

A different perspective is provided by Keynesian economists who defend that by increasing the demand for goods and services, public investment stimulates the economy, rising output and private investment, the multiplier effect (Romp & De Haan, 2007). When investing in public goods, such as physical infrastructures or services, the government creates a prospect for companies to invest and an economic cycle of opportunity is generated (Aschauer, 1989a, 1989b). A vast strand of the literature has thus been vindicating a significant and positive impact of public investment on private investment (e.g., Abiad et al., 2016; Argimón et al., 1997; Barbosa et al., 2016; Carrillo et al., 2018; Chipaumire et al., 2014; Dreger & Reimers, 2016; Pereira & Andraz, 2003).

Public investment in infrastructures such as airports, seaports, highways, schools, hospitals, and other social infrastructures stimulates private investment by increasing private sector productivity, creating business opportunities (Bennett, 2019). These infrastructures ensure the availability of public goods and services such as education, health, telecommunications, water supply and sewerage system, all factors that contribute to promoting private activities. There exist, on the one hand, complementarities between the two types of investments (Andrade & Duarte, 2016; Argimón et al., 1997; Erden & Holcombe, 2005) with public investment raising the marginal product of private investment (Cavallo & Daude, 2011) and, on another hand, positive spillovers from public investment to other sectors of the economy (Masten & Gnip, 2019). Public investment raises output, crowds in private investment, and decreases unemployment (Abiad et al., 2016). Additionally, governments can promote private investment through public expenditures by ensuring an adequate political and institutional environment that reduces uncertainty (Barbosa et al., 2016). To encourage private firms to undertake their projects, governments can introduce public incentives such as tax reductions or subsidizing policies.

The size of fiscal multipliers can be decisive in this domain. Blanchard and Leigh (2013, 2014) showed these multipliers increasing during downturns even above 1, while Górnicka et al. (2020) estimate them to be less than 1. Ilzetzki et al. (2013) showed fiscal multipliers depending on variables such as the level of development, the exchange rate regime, the degree of openness to trade, and the level of public indebtedness, while Mittnik and Semmler (2012) concluded that the timing of the demand shocks matters, the fiscal expansion multiplier tending to be larger when economic activity is in a phase of expansion. Ramey (2019) has estimated the multipliers on general government purchases to be within the narrow range of 0.6 to 1. According to the IMF (2014), public infrastructure investment raises output in both the short and long term. These effects are reinforced during periods of economic slack and when investment efficiency is high, and the multiplier tends to be larger for countries with low public debt ratios.

The level of a country's development can also shape the relationship between public and private capital. Erden and Holcombe (2005) conclude that public investment complements private investment in developing countries but crowds out private investment in industrial economies. Crowding-out effects are the outcome of the two investments competing for the same resources and of declining productivity in the private sector in response to a larger public sector. In developing economies, where the level of capital accumulation is lower, the public sector builds infrastructures that are complementary to private investment. Public investment is an important driver of economic growth in advanced economies, principally when directed to infrastructures, while in developing economies both public investment and private investment are important components of economic growth (Makuyana & Odhiambo, 2016). Among a set of Sub-Saharian countries, public investment is seen to facilitate private investment, and its impact will be greater the higher the level of development of the private sector (Ouédraogo et al., 2019).

Distinguishing between productive sectors can also be relevant for the crowding-in versus crowding-out outcome. Public capital has positive effects on private capital as a whole but changes the composition of private investment, leading to its concentration in a specific sector such as the manufacturing sectors, public utilities and communications (Pereira & Andraz, 2003). Studying Pakistan, Saeed et al. (2006) found crowding-in effects of

public investment in the agricultural sector but crowding-out effects in the industrial sector. Likewise, the quality of institutions and the degree of openness are found to affect this equation, Cavallo and Daude (2011) showing the crowing-out effect they detected within a large group of countries to be reversed in countries with better institutions and more open to international trade and financial flows. Xu and Yan (2014) analysing China, conclude that when government investment is in public goods there is a crowding-in effect on private investment, while when government investment is in private goods meaning through state-owned enterprises, it crowds out private investment. The literature has also been reporting crowding-in effects of public investment in private investment in the short run and crowding-out effects in the long run (Nguyen & Trinh, 2018) as different results for the type of relationship depending on the period that is under analysis (Bahal et al., 2018).

Overall, there is still no consensus on the direction of the link between public and private investment. Mixed evidence on this subject suggests it should be explored the possibility of occurring qualitative changes in this relationship given the macroeconomic context. This paper contributes to this literature by exploring if there exists a nonlinear relationship between public investment and private investment.

3 | PUBLIC INVESTMENT, PRIVATE INVESTMENT AND ECONOMIC GROWTH

A first inspection of the data show the strong connection between government investment and private investment within this sample of countries whose correlations for the period 2000–2019 are displayed in Figure 1. Private investment is the natural log of the gross fixed capital formation of the private sector at current prices measured in millions of euros and divided by the investment deflator. Public investment is the natural log of the general government gross fixed capital formation at current prices converted into real public investment through its division by the consumer price index (CPI). All variables were retrieved from the AMECO database (Ameco, 2021). The positive correlation between public and private investment within this group suggests a crowding-in effect in a way that as public investment increases, private investment will also tend to increase.

Further analyses are carried out, separating total observations into two groups given pre-determined levels of the ratio of public to private investment, the growth rate of GDP and the interest rate, displayed in Figures 2a to 4b. Figure 2a,b separate the sample respectively for a

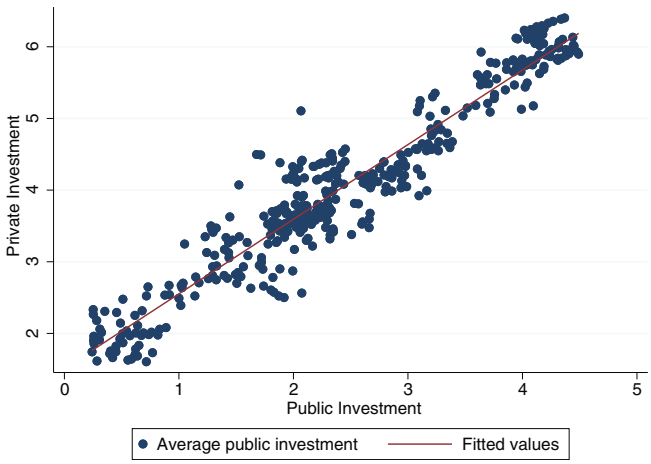

FIGURE 1 Correlation between the log of private investment and the log of public investment. *Source*: Ameco database [Colour figure can be viewed at wileyonlinelibrary.com]

ratio of public to private investment below and above 20%, a level that is based on OECD (2021a, 2021b) which indicates 15% as the current share of public investment to total investment among this group of countries. Figure 3a,b present the same correlations splitting the sample according to a growth rate of GDP below and above 2%, which represents both the average growth rate of advanced economies in their long-run equilibrium as the iron law of convergence (Barro, 2015). Figure 4a,b split the pairs of observations for levels of the annual nominal interest rate above and below 2%, respectively. This value corresponds to the long-run interest rate that is incorporated by modern central banks in their monetary policy rules (Taylor, 1993). In all figures, a linear fit was adjusted for the pairs of correlations.

A close inspection of these figures cannot detect significant differences between the two groups by either criterion. The most meaningful difference results from the ratio of public to private investment, whose slope by construction differs between the two distributions (Figure 2a,b). It is also evident that according to the three chosen thresholds, the distributions are slightly asymmetric, the majority of the pairs being above the respective tipping points. The next step is thus to investigate if there is an endogenous threshold for these variables moulding the relationship between public investment and private investment.

4 | MODEL SETUP AND VARIABLES

4.1 | Linear model and data

The linear specification of the empirical model used in this study can be represented by the following regression,

in which private investment (*PrInv*) is explained by public sector investment (*PubInv*) and a set of control variables:

$$PrInv_{i,t} = \beta_0 + \beta_1 PubInv_{i,t} + \beta_2 GGDP_{i,t} + \beta_3 Int_{it} + \beta_4 Debt_{ti} + \beta_5 FDI_{it} + \beta_6 Sav_{it} + \varepsilon_{i,t} \quad (1)$$

where i denotes countries, t denotes years, and $\varepsilon_{i,t}$ is an error term.

The dependent variable in this model is the natural log of real private investment and the main explanatory variable is the natural logarithm of real public investment, both variables defined in Section 3. Given the lack of consensus in the literature, this paper goal is to estimate the sign of this variable coefficient, to establish the impact of public investment on private investment. Theoretically, in the IS-LM model, the increase in aggregate demand resulting from public investment generates competition for sources of financing that causes the interest rate to rise, harming private investment—the crowding-out effect (a negative sign). Another view considers that, especially in times of economic recession, by stimulating economic growth through its multiplier effect, increased public investment has the effect of stimulating private investment—the crowding-in effect (a positive sign).

Among control variables, the model includes the growth rate of GDP (*GGDP*) measured in percentage and collected from The World Bank Development Indicators

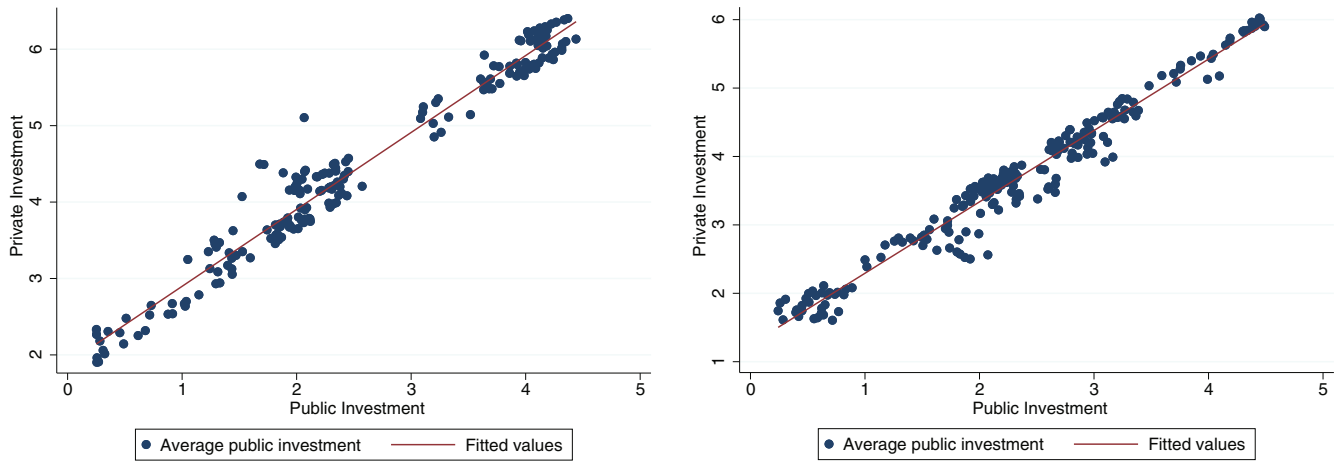

FIGURE 2 (a) Correlation between the log of private and of public investment for a ratio of public to private investment <0.2. (b) Correlation between the log of private and of public investment for high levels of a ratio of public to private investment ≥0.2. *Source*: Ameco database [Colour figure can be viewed at wileyonlinelibrary.com]

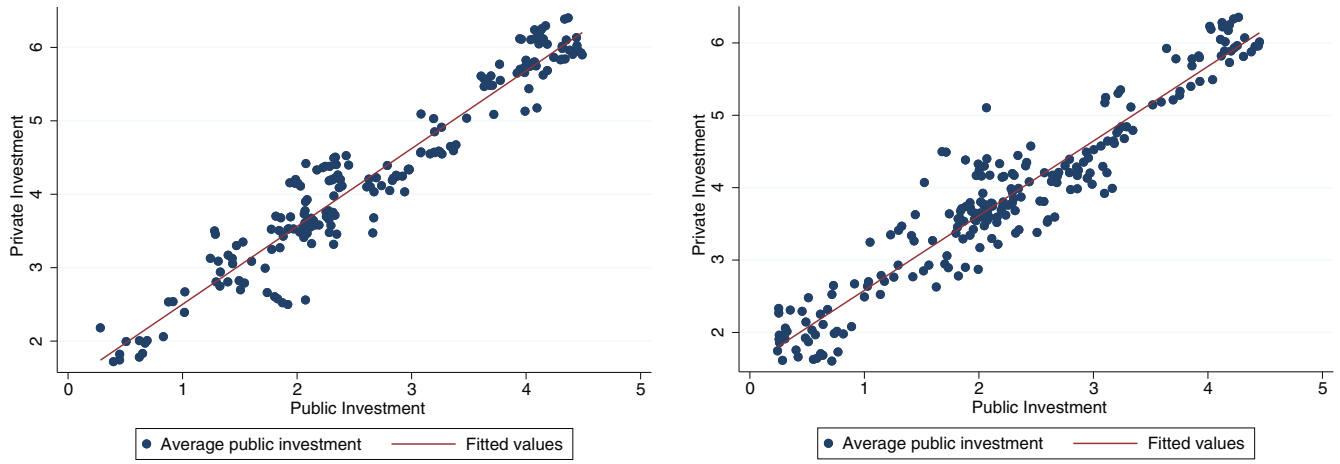

FIGURE 3 (a) Correlation between the log of private and of public investment for a growth rate of GDP <2%.(b) Correlation between the log of private and of public investment for a growth rate of GDP ≥2%. *Source*: Ameco database [Colour figure can be viewed at wileyonlinelibrary.com]

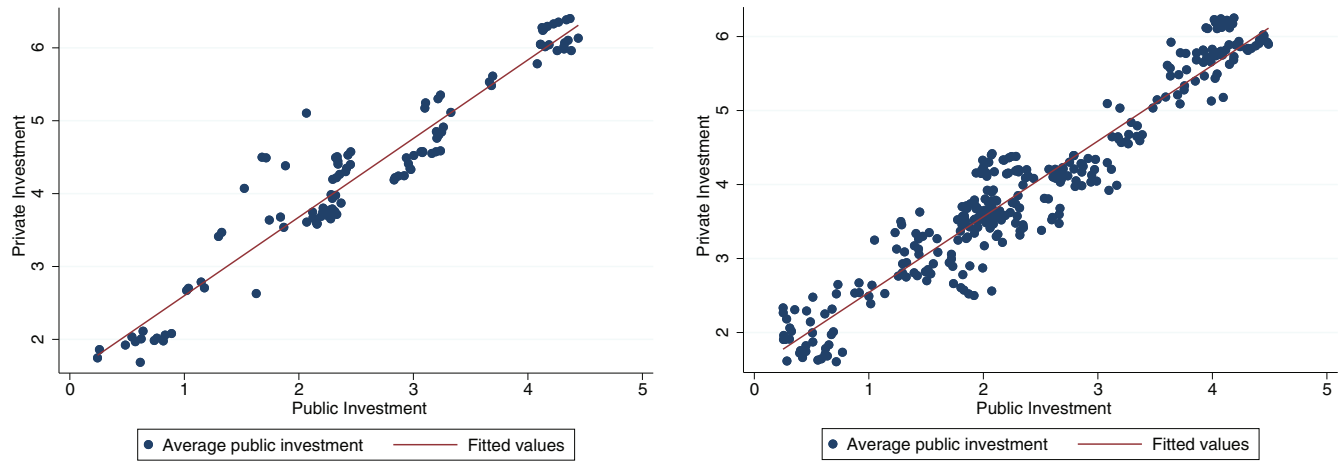

FIGURE 4 (a) Correlation between the log of private and of public investment for an interest rate <2%. (b) Correlation between the log of private and of public investment for an interest rate ≥2%. *Source*: Ameco database [Colour figure can be viewed at wileyonlinelibrary.com]

(WDI, 2021) database. Since, from the accelerator principle, the business sector reacts to improved economic conditions by increasing investment, the expected sign for this variable coefficient is positive. *Int* corresponds to the annual real interest rate calculated using the annual interest rate extracted from the OECD Database, measured in percentage and corrected for inflation using CPI. Being an element of the user cost of capital (Bosco & Emerence, 2016), whose increase is often faced as a consequence of public investment financing (Afonso & St. Aubyn, 2009; Dreger & Reimers, 2016), it is expected to display a negative coefficient in the estimations. The general government debt as a percentage of GDP (*Debt*), collected from the OECD database is another independent variable. By contributing to the rise of the interest rate, this ratio is a significant factor in the sustainability of government finance and may affect the size of the multiplier (IMF, 2014), consequently, its coefficient is expected to be negative. Foreign direct investment (*FDI*) as net inflows from foreign investors as a percentage of GDP and extracted from WDI is another control variable. The inflows of FDI may reduce the crowding-out effect of public investment by increasing loanable funds in the domestic financial market (Dash, 2016), thus its coefficient is expected to be positive. Finally, the model includes gross savings as a percentage of GDP (*Sav*) gathered from the WDI database, with positive expected coefficient, representing the fraction of disposable income that is available to invest. A summary of descriptive statistics on these variables is displayed in Table 1.

To assure some robustness tests, besides this model there were estimated a model without savings and another without savings and FDI.

4.2 | Threshold model

The effect that public investment exerts on private investment may depend on the amount of public investment that is undertaken or on the level of variables that impact its transmission mechanisms, namely the growth rate of GDP that affects the accelerator or the level of the interest rate that changes the user cost of capital. These possibilities are tested by applying linear threshold regressions to the previous model using the panel threshold method proposed by Hansen (1999, 2000). The previous model with J thresholds could be represented as follows:

$$\begin{aligned} PrInv_{it} = {} & \beta_0 + \beta_1 GGDP_{it} + \beta_2 Int_{it} + \beta_3 Debt_{ti} + \beta_4 FDI_{it} \\ & + \beta_5 Sav_{it} \\ & + (\delta_1 + \alpha_1 PubInv_{it}) + .\mathrm{I}(PubInv_{it} \ll \gamma_1) \\ & + \sum_{j=2}^{J} (\delta_j + \alpha_j PubInv_{it}).\mathrm{I}\left(\gamma_{j-1} < PubInv_{it} \ll \gamma_j\right) \\ & + (\delta_{j+1} + \alpha_{j+1} PubInv_{it}).\mathrm{I}\left(PubInv_{it} > \gamma_j\right) + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where $I(\cdot)$ is an index function and γ represents the j thresholds and the threshold value and its number are completely determined by the sample data. This model shows that the partial effect of public investment is specific to the group that verifies the threshold range. The error term can be decomposed as $\varepsilon_{it} = \mu_i + \epsilon_t + \upsilon_{it}$, μ_i representing the unobservable country fixed effects, ϵ_t the unobservable time fixed effects and υ_{it} the random

TABLE 1 Variables' descriptive statistics

	Mean	*SD*	Min	Max
Private investment	4.0452	1.2344	1.6060	6.4026
Public investment	2.4338	1.1353	0.2422	4.4907
GDP growth	2.0829	2.8695	−10.1493	25.1763
Interest rate	4.3160	2.9395	−0.2405	21.7535
Public debt	75.1515	35.2407	17.1377	200.8267
FDI	6.3587	13.2514	−57.5323	86.4792
Savings	23.3405	6.1878	4.6613	41.8895

error. Hansen (1999) suggested minimizing the sum of square residuals from a consistent estimation. The hypotheses that represent the test for the presence of thresholds γ_1 to γ_j are given by:

$$\begin{array}{ll} \gamma_1 : H_0^1 : \alpha_1 = \alpha_2 & H_1^1 : \alpha_1 \neq \alpha_2 \\ \vdots & \vdots \\ \gamma_j : H_0^j : \alpha_j = \alpha_{j+1} & H_1^j : \alpha_j \neq \alpha_{j+1} \end{array} \quad (3)$$

The hypotheses are tested through an F function simulated through a bootstrap procedure. If the last null hypothesis is not rejected the model has only thresholds up to $j-1$.

Seo and Shin (2016) suggest a new approach to apply to dynamic panel threshold models by extending the static panel data threshold estimator from Hansen (1999, 2000) and generalizing the Arellano and Bond (1991) GMM model. In this approach, it is possible to account for endogenous regressors and endogenous threshold variables. Estimations with dynamic panel data, which control for any endogeneity that may exist among variables, were used as robustness tests to the baseline estimations.

5 | RESULTS AND DISCUSSION

5.1 | Linear effects

To make sure that is possible to proceed with the estimations, panel data unit root tests by Levin et al. (2002) were applied to all variables (see Table 2), the null hypothesis of the unit root test being rejected for all variables.

Next, the regressions were estimated using panel fixed effects, after applying a Hausman test to choose between these and panel random effects, concluding the former were preferred over the latter. To ensure that the fixed effects estimation was efficient the modified Wald test to detect groupwise heteroscedasticity in the residuals was applied, the errors revealing groupwise heteroscedasticity. The Wooldridge test for serial correlation in the idiosyncratic errors indicated the presence of autocorrelation in the residuals. These tests led to the estimation of the linear model using a covariance matrix estimator proposed by Driscoll and Kraay (1998) that produces heteroscedastic and autocorrelated standard errors that are robust to cross-sectional dependence (Hoechle, 2007). A lag length of two was used by default. Table 3 displays the fixed effects estimations results for different model specifications.

TABLE 2 Levin et al. (2002) panel unit root test

Private investment	−5.7686*
Public investment	−5.2111**
GDP growth	−12.8947***
Interest rate	−4.0092*
Public debt	−6.4459***
FDI	−16.1415***
Savings	−8.6802***

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Except for the growth rate of GDP and FDI, the linear estimations confirm all variables have a statistically significant influence on private investment. In column (2) savings were eliminated as an independent variable and since total private investment abridges FDI, in column (3) both FDI and savings were eliminated from the model. In the three specifications, the results are consistent and robust, displaying the same signs and a similar range for the coefficients of the independent variables.

Government investment is shown to exert a significant and positive effect on private investment implying the existence of a crowding-in effect. A 1% increase in public investment can yield about a 0.22% to 0.26% increase in private investment, suggesting high complementarity between public infrastructures and private investment among this group, corroborating the findings of Argimón et al. (1997) and Abiad et al. (2016).

TABLE 3 Fixed effects estimations results

	(1)	(2)	(3)
Public investment	0.257***	0.225***	0.224***
	(0.0577)	(0.0105)	(0.0746)
GDP growth	0.00334	0.0105***	0.0109***
	(0.00375)	(0.00280)	(0.00268)
Interest rate	−0.0314***	−0.0360***	−0.0357***
	(0.00671)	(0.00871)	(0.00879)
Public debt	−0.00506***	−0.00570***	−0.00568***
	(0.000927)	(0.00106)	(0.00106)
FDI	0.00112	0.000565	
	(0.000971)	(0.00103)	
Savings	0.0144**		
	(0.00585)		
Constant	3.617***	4.901***	4.093***
	(0.236)	(0.291)	(0.292)
No. observations	420	420	420
R-squared	0.5362	0.5102	0.5094

Note: The models in Columns (1), (2) and (3) were estimated applying Driscoll-Kraay standard errors. Standard errors within brackets. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Control variables display the expected results. A one percentage point increase in the GDP growth rate raises private investment by 1%, corroborating the presence of an accelerator mechanism in line with Voss (2002) and Suhendra and Anwar (2014). An increase of one percentage point in the interest rate is found to reduce private investment by 3.1 to 3.6% corroborating Dreger and Reimers' (2016) findings for the euro area. General government debt displays a negative relationship with private investment, an outcome consistent with Huang et al. (2018) and the thesis that poor financial conditions from increases in public debt discourage investment by firms (Dreger & Brautzsch, 1999). Foreign direct investment coefficients indicate a positive but non-significant impact on private investment. FDI raises the level of private investment while injecting money into the economy, increasing the country's financial slack and improving private firms' economic conditions. Lastly, savings are shown to positively impact private investment as expected. The similarity between the three settings confirms the model's robustness.

5.2 | Nonlinear effects

The models were estimated under the assumption of no threshold and a single threshold, while tests for a second threshold were also run and rejected for all specifications. Accordingly, each model captures the impact of public investment on private investment in two different regimes. Results based on nonlinear specifications, estimated by applying a data-driven approach, are presented in Tables 4 to 7 considering as threshold variables, respectively, the natural log of public investment, the ratio of public investment to private investment, the growth rate of GDP and the real interest rate.

There was found evidence of nonlinear effects for the relationship between the set of independent variables and private investment. In three specifications (in which the ratio of public to private investment, the growth rate of real GDP and the interest rate are the threshold variables), all the bootstrapped tests strongly reject the null hypothesis of linearity (one regime) in favour of a nonlinear relationship between public investment and private investment. The threshold value for each variable lies around 1.7 for the log of public investment (non-significant), 8% for the ratio of public to private investment, 4.8% for the growth rate of GDP, and 1.4% for the interest rate. The results for these estimations can once more be considered robust.

Table 4 displays results for nonlinear estimations when the log of real public investment is the threshold variable (not statistically significant), corroborating the crowding-in effect from previous estimations but revealing a stronger effect of public investment on private investment when the former variable is below its tipping

TABLE 4 The nonlinear relationship between public investment and private investment, the log of public investment as the threshold variable

	(1)	(2)	(3)
Threshold (%)	1.7206	2.4296	2.4296
Bootstrapped p-value	0.4767	0.5100	0.4900
Public Inv. α_1	0.3574***	0.0892**	0.0881**
	(0.0497)	(0.04431)	(0.0442)
Public Inv. α_2	0.2518***	0.1628***	0.1619***
	(0.0396)	(0.0398)	(0.0398)
GDP growth	−0.0001	0.0061***	0.0064**
	(0.0031)	(0.0029)	(0.0028)
Interest rate	−0.0364***	−0.0400***	−0.0398***
	(0.0040)	(0.0040)	(0.0040)
Public debt	−0.0035***	−0.0039***	−0.0039***
	(0.0005)	(0.0005)	(0.0005)
FDI	0.0008	0.0004	
	(0.0006)	(0.0006)	
Savings	0.0154***		
	(0.0027)		
Constant	3.4666***	4.1690***	4.1711***
	(0.1619)	(0.1406)	(0.1404)
No. observations	420	420	420
R-squared	0.542	0.507	0.507
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). *p*-values are from repeating bootstrap procedures 300 times. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

TABLE 5 The nonlinear relationship between public investment and private investment, the ratio of public investment to private investment as the threshold variable

	(1)	(2)	(3)
Threshold (%)	0.0821***	0.0821***	0.0821***
Bootstrapped p-value	0.0000	0.0000	0.0000
Public Inv. α_1	0.708***	0.721***	0.721***
	(0.0491)	(0.0489)	(0.0489)
Public Inv. α_2	0.206***	0.195***	0.194***
	(0.0329)	(0.0326)	(0.0325)
GDP growth	−0.0017	0.0006	0.0007
	(0.0026)	(0.0024)	(0.764)
Interest rate	−0.0342***	−0.0356***	−0.0355***
	(0.0034)	(0.0033)	(0.0033)
Public debt	−0.0037***	−0.0039***	−0.0039***
	(0.0004)	(0.0004)	(0.0004)
FDI	0.0004	0.0002	
	(0.0005)	(0.0005)	
Savings	0.0052		
	(0.0024)		
Constant	3.838***	4.007***	4.008***
	(0.1380)	(0.1137)	(0.114)
No. observations	420	420	420
R-squared	0.671	0.667	0.667
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). *p*-values are from repeating bootstrap procedures 300 times. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

point, namely a 1% increase in public investment gives rise to 0.36% increase against 0.25% when respectively under or above the threshold, the two coefficients being statistically significant at the 1% significance level. The crowding-in result for the two regimes questions the strand of the literature which has been advocating that government investment tends to compromise investment by the private sector (e.g., Cevik, 2020; Voss, 2002) and rejects the idea that these countries could lack the absorptive capacity to deal with higher public investment as put forward by Presbitero (2016) for emerging economies. However, the lower coefficient for the regime with greater public investment may be pointing out to decreasing marginal productivity of public capital for greater levels of investment. The higher the level of government investment in the construction of public infrastructures, the lower the costs of investing in new plants and, through the multiplier effect, the higher the potential demand that is directed to firms, two factors that combined promote an adequate economic environment to private investment. Nevertheless, above a certain threshold of public capital, its crowding-in effect becomes weaker.

The country dimension, which impacts the levels of both private and public investment, might be biasing the previous results. To control for this fact, Table 5 displays estimations for a nonlinear model where the ratio of public investment to private investment is tested for a tipping point. The null hypothesis of a linear model is once again rejected at the 5% significance level, the threshold being fixed at 8%. When the ratio of public to private investment is below its optimal level the coefficient for the impact of public investment is about 0.71 and when the threshold variable is above its optimal level this value is reduced to 0.21. The two regimes produce crowding-in effects, more prominent for relatively lower levels of government investment reinforcing the suggestion of

diminishing marginal returns for higher levels of public capital. As a policy implication these outcomes imply that, in countries where low levels of private investment compromise their macroeconomic performance, governments can develop aggressive public investment policies to trigger private investment without being afraid of overtaking a point where they will crowd out private investment. Nevertheless, the impact of the first units of public capital should be expected to attract more private investment than the remaining ones possibly due to being more productive. The estimated threshold for this ratio of about 8% is above OECD countries' average ratios of public to private investment which is now 17%.

To the extent that economic growth contributes to the accelerator mechanism, a nonlinear effect between public and private investment could explain a positive correlation for high levels of economic growth and a negative correlation otherwise. Table 6 contains the results of the estimations for the impact of a threshold on the growth rate of GDP. The impact is small: confirming the findings from Figure 3a,b, a growth rate below its optimal level, estimated at around 5%, is associated with a marginally stronger crowding-in effect of public investment on private investment, both coefficients being statistically significant. It is then likely that fiscal stimulus measures are more efficient within a context of slower economic growth, increasing output and encouraging private investment. As suggested by Argimón et al. (1997), when public infrastructures investment projects generate positive externalities that increase productivity and produce economies of scale, they can at once push economic growth to higher levels and incite private investment. However, the proximity of the results between the estimated coefficients for the two regimes points to other variables being more relevant to define the qualitative change in this impact.

The literature has emphasized how the cost of investment financing appraised through the interest rate can depend on the level of public investment and even condition its impact on private investment. Table 7 displays the results of estimations with an optimal threshold for the interest rate, indicated to be around 1.4%. The positive and statistically significant effect that public investment has on private investment is not very different in both regimes. The coefficient relating public to private investment is higher in the regime where the interest rate is under its tipping point. The impact decreases when additional sources of investment financing (savings and FDI) are eliminated from the model. Policymakers should thus care about these alternative sources of funds when evaluating the impact public investment may have on private investment.

To verify the results obtained for the static models, we performed additional estimations using the GMM methodology from Seo and Shin (2016), which are presented in Table 8. To avoid the proliferation of the number of instruments in the dynamic model, the original data were converted to 3-year averages. For the sake of space, only the results of the full model are disclosed, given that the other estimations results are in line with those presented. The GMM estimation results are reported for the low regime and the additional effect above the threshold.

Dynamic panel data models corroborate the existence of nonlinearities in the relationship between public

TABLE 6 The nonlinear relationship between public investment and private investment, the growth rate of GDP as the threshold variable

	(1)	(2)	(3)
Threshold (%)	4.8154**	4.8154***	4.8154***
Bootstrapped p-value	0.0133	0.0000	0.0033
Public Inv. α_1	0.1891***	0.1367***	0.1383***
	(0.0382)	(0.0384)	(0.0383)
Public Inv. α_2	0.1187**	0.0936***	0.0973***
	(0.0447)	(0.0448)	(0.0445)
No. observations	420	420	420
R-squared	0.574	0.538	0.535
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). p-values are from repeating bootstrap procedures 300 times. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

TABLE 7 The nonlinear relationship between public investment and private investment, the real interest rate as the threshold variable

	(1)	(2)	(3)
Threshold (%)	1.3980**	1.3980*	1.3980
Bootstrapped p-value	0.0300	0.0967	0.1767
Public Inv. α_1	0.4377***	0.2223***	0.2201***
	(0.0308)	(0.0401)	(0.0401)
Public Inv. α_2	0.3802***	0.1798***	0.1783***
	(0.0320)	(0.0393)	(0.0393)
No. observations	420	420	420
R-squared	0.490	0.516	0.514
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). p-values are from repeating bootstrap procedures 300 times. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

TABLE 8 Dynamic threshold panel data model of private investment

	Threshold variable			
	Public investment	**Ratio public inv./private inv.**	**GDP growth rate**	**Interest rate**
Threshold	1.604***	0.126***	4.638***	4.528**
	(0.306)	(0.0204)	(0.181)	(1.833)
C.I.	[1.00–2.20]	[0.09–0.17]	[4.28–1.99]	[0.94–8.12]
Linearity (*p*-value)	0.0	0.0	0.0	0.0
Public Inv.	0.190	0.765**	0.335**	0.626***
	(0.173)	(0.339)	(0.133)	(0.138)
Additional effect above threshold	0.248*	0.493***	−0.342**	−0.130**
	(0.146)	(0.121)	(0.145)	(0.0659)

Note: Standard errors within brackets. The dependent variable is the log of private investment. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

investment and private investment, attesting to the existence of threshold values at which there is a qualitative change in the impact that the former has on the latter. Except for the interest rate, whose tipping point is much higher in the dynamic estimates, placed at 4.5%, the results do not differ considerably from those of estimations with static panel data: when the logarithm of public investment is the transition variable, its threshold is now statistically significant; and, the thresholds values are very close to the values shown respectively in Tables 4, 5 and 6. The effect of public investment on private investment is positive in virtually all cases, becoming only slightly negative in the case of the regime above the tipping point for the model in which the GDP growth rate sets the threshold. Overall, the dynamic models confirm nonlinearities and the predominance of the crowding in effect in the different regimes.

5.3 | The effect of the unconventional monetary policy

The previous analysis treated the 2000–2019 period as a homogeneous whole, ignoring the role that after the financial crisis the adoption of new monetary tools by central banks may have had on the relationship between public investment and private investment. By dampening the effect of government debt on economic activity, the non-standard monetary policy gave rise to government spending that would otherwise have been impossible, which may have allowed for crowding-in type effects. Nevertheless, a monetary policy that keeps interest rates low may lead to decreased fiscal discipline, the low cost of public funding incentivizing governments to increase public spending (Debrun et al., 2021). As unconventional monetary policy has been introduced by several central banks to address the exhaustion of fiscal policy in their countries, it is expected to have influenced the response of private investors to public investment. This section reflects on this issue, estimating the previous models but distinguishing the period between 2000 and 2008 from the period after 2009, which was characterized by crisis and non-standard monetary policy measures.

Tables 9 and 10 present the estimates of the models considering the three different thresholds that proved to be statistically significant when the static model was applied to the whole period, distinguishing respectively the period before and after the adoption of the unconventional monetary policy. In both cases, only the thresholds for the ratio between public and private investment and for the real interest rate are statistically significant. These two thresholds are substantially lower in the more accommodative monetary policy scenario: for the ratio of public to private investment, the tipping point after the introduction of UMP coincides with the one calculated for the complete period (see Table 5); for the interest rate, the threshold increases for each sub-period in comparison to the estimate for 2000–2019.

In both scenarios, the crowding-in impact of public investment is greatest in the regime below the threshold for either the ratio of public to private investment or the interest rate. When the ratio of public to private investment defines the threshold, the impact in the lower regime is substantially diminished in the two sub-periods compared with the full period. These results possibly indicate the disruption caused by the financial crisis on public and private investment, with the former contracting due to fiscal discipline and the latter contracting due to a lack of confidence in the economy and the reduction of public stimulus.

When the interest rate is the threshold, the difference in regimes points to a stronger crowding-in impact when

TABLE 9 The nonlinear relationship between public investment and private investment, conventional monetary policy

	Threshold variable		
	Ratio public Inv./private Inv.	**GDP growth rate**	**Interest rate**
Threshold (%)	0.3089***	5.7734	5.1338**
Bootstrapped p-value	0.0100	0.7367	0.0467
Public Inv. α_1	0.3912***	0.3155***	0.3956***
	(0.0449)	(0.0448)	(0.0385)
Public Inv. α_2	0.2982***	0.2884**	0.3709***
	(0.0418)	(0.0462)	(0.0398)
No. observations	189	189	189
R-squared	0.606	0.548	0.531
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). p-values are from repeating bootstrap procedures 300 times. ***, and ** indicate significance at the 1% and 5% levels, respectively.

TABLE 10 The nonlinear relationship between public investment and private investment, unconventional monetary policy

	Threshold variable		
	Ratio public Inv./private Inv	**GDP growth rate**	**Interest rate**
Threshold (%)	0.1085***	−6.5955	2.9867***
Bootstrapped p-value	0.0100	0.1400	0.0000
Public Inv. α_1	0.3709***	0.2347***	0.1609***
	(0.0672)	(0.0746)	(0.0465)
Public Inv. α_2	0.0508	0.0843**	0.1065**
	(0.0479)	(0.0530)	(0.0472)
No. observations	231	231	231
R-squared	0.696	0.644	0.651
Number of id	21	21	21

Note: Standard errors within brackets. The dependent variable is the log of private investment. Each regime contains at least 5% of all observations (Hansen, 1999). p-values are from repeating bootstrap procedures 300 times. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

economies are below the threshold in either sub-period, but the stimulus effect that public investment has on private investment is greater before the need to use UMP measures. The estimates are in line with those obtained for the ratio of public investment to private investment—the crowding in effect is less pronounced after 2009. The decrease in the interest rate threshold under the effect of the UMP points to a period when expansionary monetary policy was the way to avoid greater fiscal imbalances.

All in all, the results suggest more demanding conditions for a high crowding-in effect after the adoption of unconventional policy measures, which most likely reflects the impact that the economic crisis had on these relations.

The threshold models were re-estimated using the dynamic panel data method of Seo and Shin (2016) which accounts for endogenous regressors and threshold variables, the results being displayed in Tables 11 and 12. Since in the dynamic estimations all the tipping points were statistically significant, the models were run for the four threshold variables. Nonlinearity is rejected for the effect of the logarithm of public investment and the interest rate during the conventional monetary policy period, and all the tipping points are higher when post-UMP, corroborating the fixed-effects findings. After the adoption of UMP, the threshold for the interest rate is not statistically significant. In the two regimes, when the coefficients for the impact of public capital on private capital are statistically significant, the crowding in effect is dominant, in line with previous findings. There was found a single exception for the regime above the threshold for the real interest rate and after the introduction of the UMP, which may express the negative effect that public spending may have had on agents' expectations during a period marked by sovereign debt crises.

TABLE 11 Dynamic threshold panel data model of private investment, conventional monetary policy

	Threshold variable			
	Public investment	**Ratio public Inv./private Inv.**	**GDP growth rate**	**Interest rate**
Threshold	2.327***	0.207***	2.682***	4.876***
	(0.767)	(0.0232)	(0.533)	(1.019)
C.I.	[0.82–3.83]	[0.16–0.25]	[1.64–3.73]	[2.88–6.87]
Linearity (*p*-value)	0.83	0.05	0.09	0.97
Public Inv.	1.093***	0.687***	0.959***	0.914***
	(0.253)	(0.108)	(0.223)	(0.191)
Additional effect above threshold	−0.802***	−0.163*	−0.374**	−0.421*
	(0.284)	(0.0840)	(0.181)	(0.216)

Note: Standard errors within brackets. The dependent variable is the log of private investment. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

TABLE 12 Dynamic threshold panel data model of private investment, unconventional monetary policy

	Threshold variable			
	Public investment	**Ratio public Inv./private Inv.**	**GDP growth rate**	**Interest rate**
Threshold	2.953***	0.133***	4.127***	0.618
	(0.591)	(0.0167)	(0.0966)	(0.5305)
C.I.	[1.80–4.11]	[0.10–0.17]	[3.94–4.32]	[−0.42–1.66]
Linearity (*p*-value)	0.0	0.0	0.0	0.0
Public Inv.	−0.0626	0.114	0.250***	0.034***
	(0.127)	(0.232)	(0.0829)	(0.808)
Additional effect above threshold	−0.213	0.357*	0.900***	−0.148***
	(0.494)	(0.200)	(0.169)	(0.016)

Note: Standard errors within brackets. The dependent variable is the log of private investment. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

6 | CONCLUSION

Despite extensive research, the issue of what type of effects public investment cause on private investment continues to produce ambiguous empirical results. Several explanations have been put forward for the contradictory findings, but few efforts have been made to take into account the qualitative change that can occur in this relationship when different macroeconomic fundamentals overtake a given tipping point.

This paper tried to fill this gap in the literature by exploring if there is a nonlinear relationship between private investment and public investment in a sample of 21 OECD countries. Using panel data threshold methodologies, it was inspected to what extent nonlinearities are the result either of the amount of public investment that is undertaken or of specific macroeconomic features, particularly the growth rate of GDP and the level of the interest rate. The empirical findings indicate that the existence of two regimes cannot be statistically rejected in all cases, one of the regimes producing stronger crowding-in effects of public investment in private investment. The magnitude of the impact was found to be higher in the lower regimes for all threshold variables, signposting a role for the law of diminishing returns in this relationship. The robustness of the static estimations was confirmed through dynamic panel models that allow controlling for the existence of endogeneity among the different variables.

The introduction of unconventional monetary policy has not eliminated the existence of nonlinearities or the positive effect of public investment on private investment, although it is shown to affect the tipping points for the different variables assumed as thresholds.

In terms of policy implications, the current empirical analysis advocates that an increase in public investment acts as a decisive stimulus for private investment. Private agents seem to react to what usually are major infrastructures by increasing their investment, responding at once to the new facilities that are created for their own business and to the boost in demand that is the result of

increased public expenditures. Firms seem to need incentives when what is at stake is to increase their productive capacity through the acquisition of physical capital, a risky activity involving short-run costs and long-run returns. Policymakers aware of the positive answer to public investment from firms, and having to deal with a new crisis, can use it as a way to boost private investment, enhance economic growth and create new jobs.

AUTHOR CONTRIBUTIONS

Both authors developed the idea. The author, Sofia Vale analyzed the results, and wrote the article. Sofia São Marcos organized the data and estimated the econometric model under the supervision of Sofia Vale. Both authors edited the article. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

Expects Data Policy: not applicable to this article as no new data were created or analyzed in this study, all data were derived from public domain resources.

ORCID

Sofia Vale https://orcid.org/0000-0002-1074-4711

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APPENDIX A

A.1 | Data Sources

AMECO, annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/macro-economic-database-ameco/ameco-database_en.

BIS, Bank of International Settlements, https://stats.bis.org/statx/toc/LBS.html.

OECD Stat, Organization for Economic Cooperation and Development, http://stats.oecd.org/.

World Bank Development Indicators (WDI) https://databank.worldbank.org/source/world-development-indicators.