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Abstract

We study the impacts of public investment, notably in construction and in R&D on economic growth and of crowding-out effects on private investment. For this purpose, we use Panel Vector Autoregression (PVAR) models and the Generalised Method of Moments (GMM) approach for 40 advanced and emerging countries from 1995 to 2019. Our findings are as follows: i) innovations in public investment have more positive effects on GDP growth and private investment in emerging economies; ii) the positive impulse of public investment on private sector is pronounced and significant in emerging economies; iii) government construction investment has a more positive effect on economic growth in emerging economies; iv) innovations in public construction crowd-out private investment spending in advanced countries; v) emerging economies benefit from public R&D investment; vi) the public investment multiplier of the full sample is 1.67, while it is 0.87 for advanced economies and 2.29 for emerging economies.

JEL-Codes: C330, E320, H540.

Keywords: public investment, construction, research & development, PVAR.

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1. Introduction

Investments in infrastructure and research and development (R&D) are prominent sources of growth for both the private sector and the government. Despite the possible scepticism about fiscal effectiveness in boosting economic activity, the justification for the government presence is the idea of non-rival goods and the need for investments of uncertain return, but with socially important outcomes (Van Elk *et al*., 2019; Ramey, 2020).

The roots of this scepticism refer to the role of government and the degree of intervention in the economy. Thus, prominent authors such as Friedrich Hayek and Milton Friedman compose a strand of literature that defends individual freedom and the absence of external coercion, that is, without the intervention of the State, which threatens the proper functioning of the market and its efficiency. On the other hand, the effectiveness of government intervention is constantly present on the agenda of governments, with greater emphasis on market self-regulation or the presence of the State to mitigate distortions arising from market failures.

However, due to the relative ineffectiveness of monetary policy to avoid long recessive periods and the lagged reaction to the financial crisis (2007-2009), fiscal stimulus stands out again in the academic literature (Feldstein, 2009). Thus, since the global financial crisis (2007 - 2009) and the economic downturn caused by the COVID-19 pandemic (2020 - 2022), we have seen an increasing prominence of the role of fiscal stimulus, and policymakers around the world have adopted expansionary fiscal policies to mitigate adverse shocks. In this respect, the American Recovery and Reinvestment Act (2010) and Biden's Economic Plan (2021) are examples of packages with an emphasis on fiscal stimulus.

Therefore, our paper contributes to the literature by using Panel Vector Autoregression (PVAR) models and the Generalised Method of Moments (GMM) approach for 40 countries between 1995 and 2019 to investigate the effects of public investment on economic growth and the evidence of the crowding-out effect on private investment. Furthermore, we examine the impact of government investment on advanced and emerging economies and whether the category of government investment (total, construction[1] and R&D) matters.

The panel model results for 40 countries suggests that innovations in public investment have positive effects beyond the first year (statistically significant) on GDP and on private investment. However, when controlling for the level of economic development, the effects are significantly different. Although the effects on economic growth are positive, they are more important for emerging economies. Furthermore, our analysis indicates that the positive

[1] Construction is defined as construction of residential and other buildings (office and industrial buildings) and infrastructure.

impulse of public investment on the private sector is no longer observed in advanced economies, but it is pronounced and significant in emerging economies.

In order to deepen the investigation, we inquire whether the category of public investment matters. Our findings indicate that government construction investment has a significant and positive influence on economic growth, more specifically in the emerging economies analysed. Regarding private investment, the impulse in public construction drives down private investment spending in advanced countries. In the opposite direction, the findings show that in emerging countries, government investment in construction stimulates private investment.

Regarding investment in R&D, our results show that public investment generates quite different effects, depending on the level of economic development. Therefore, public investment shocks have an adverse impact on GDP and on the private sector of advanced countries. On the other hand, emerging economies benefit from government intervention. In addition the public investment multiplier of the full sample is 1.67, while it is 0.87 for advanced economies and 2.29 for emerging economies.

This paper is organised as follows. Section 2 presents a brief literature review. Section 3 describes the data. Section 4 introduces the econometric strategy and Section 5 presents the empirical analysis and the respective results. The last section concludes.

2. Literature

The effects of fiscal policies on economic growth have been investigated and reassessed extensively in the economic literature. Seminal papers and recent studies (Aschauer 1989a, b; Munnell, 1990; Barro & Sala-i-Martin, 1992; Glomm & Ravikumar, 1997; Leff Yaffe, 2020; Ramey, 2020) have provided evidence that public investment fosters economic activity by positively influencing aggregate demand and through the stimulus to new private projects resulting from the increase in productivity by the physical infrastructure created.

Moreover, the literature is divided on the real effect of public capital on economic performance. After Aschauer's paper (1989a, b), other studies do not confirm the positive relationship between government investment and GDP. Sturm *et al.* (1999) and Warner (2014) find little evidence supporting public investment as a catalyst for long-term growth. Thus, depending on the cost of financing public investment and the possible crowding-out effect on private investment, the final result can be adverse and dampen economic growth (Fosu *et al.*, 2016).

In this context, several papers have tried to measure government spending multipliers. For instance, Castelnuovo & Lim (2019) present an interesting review of fiscal multipliers and the controversy about the value is still open, considering that factors such as uncertainty, level of development, periods of growth or recession and levels of public debt are key elements to understand the mixed results.

In this respect, Auerbach & Gorodnichenko (2012) point to evidence that fiscal multipliers are higher in a recession. Regarding the level of development, Batini *et al.* (2014) show that advanced economies have first-year fiscal multipliers between 0 to 1 (under standard conditions). For European countries, Kilponen *et al.* (2019) highlight that short-term multipliers have values less than one in most simulations. Afonso & Leal (2019) investigate fiscal multipliers in Eurozone countries (2000Q1-2016Q4) to understand how values are influenced by the level of public debt, the pace of economic growth and the output gap. Among other findings, they indicate that government spending has a positive effect on GDP, with an annual cumulative multiplier of 0.44. The authors also point out that the multiplier has a higher value for countries with lower levels of public debt.

For emerging economies with high debt levels, Ilzetzki *et al.* (2013) indicate negative fiscal multipliers (impact), which can be very negative in the long run (IMF, 2008). In addition, they accentuate that, both the impact and the persistence of the fiscal stimulus in developed countries are more intense. On the other hand, Carrière-Swallow *et al.* (2018) investigate the effects of fiscal shock on economic activity for 14 Latin America and Caribbean economies between 1989 and 2016. The authors suggest that the fiscal multipliers are very similar to the results found for advanced economies.

Regarding high uncertainty scenarios, Gbohoui (2021) indicates that public investment can generate positive effects on GDP if it increases the confidence of the private sector in the future of the economy. The author suggests that if communication with society is clear and expenditures are well implemented, increased public investment creates a favourable environment, signalling a commitment to economic growth.

In order to examine the reasons for the diversity of the findings, Scandizzo & Pierleoni (2020) investigate the short and long-run impacts of public investment on economic growth, examining different methodological approaches, such as DSGE and VAR. In general, the studies surveyed indicate that government investment encourages GDP and welfare. Along the same lines, Saccone *et al.* (2022) investigate 31 European countries from 1995 to 2019, using the local projection method to estimate fiscal multipliers. The findings indicate that public investment has a persistent and robust multiplier effect on economic performance.

Regarding public investment, Pereira & Frutos (1999) argue that there are no definitive conclusions about the relevance of public capital, specifically for the United States. However, Leff Yaffe, 2020 finds positive results for investments in infrastructure for the United States. In addition, other studies (Afonso & St. Aubyn, 2009, 2019; Gordon, 2016; Ramey, 2020) accentuate the relevance of public investment in different countries and highlight significant impacts on economic growth. For Ramey (2020), government construction spending, specifically infrastructure spending, stimulates the economy in the short term and drives economic activity back to potential output. In addition, public investment spending can also influence total factor productivity (TFP), raising the trajectory of potential GDP.

Concerning investment in construction and infrastructure, Nijkamp & Poot (2004) examine the effects of fiscal policy on economic performance through a meta-analysis study between 1983 and 1998. The authors examine studies indicating that the positive effect of conventional fiscal policy on growth is not very strong. However, approximately 70% of the articles report a positive impact on economic growth. In the same vein, the IMF (2014) estimates that increased investment in public infrastructure fosters GDP in both the short and long term.

Still, surprisingly, few studies assess the impact of public policies on private R&D investment, even though this spending item is largely financed by public institutions, through subsidies and investment (Soete *et al.,* 2021). In addition, the empirical studies in this area present mixed results, ranging from robust positive to negative impacts on economic growth (Van Elk, 2019).

Indeed, if there is a preponderance in the findings for investments in construction, the immediate effect of R&D on economic growth is difficult to estimate because of the time lag involved and the complex spillovers that affect different areas. Therefore, studies in the medical field can improve health outcomes without immediate effects on economic growth. Moreover, part of the research carried out in public institutions is probably indirectly related to economic growth.

Given the complexity of the topic, the image that emerges is that the relationship between public investments in R&D and economics is not robust (Van Elk, 2019). Thus, the estimated impacts of government R&D investments on economic performance vary widely, i.e., from statistically significant positive to negative effects.

Lichtenberg (1993) performs a cross-sectional study using mean public R&D expenditure for 53 countries. This paper finds neutral and negative effects on growth, but the author does not rule out indirect effects, for example, from medical research. On the other hand, Khan & Luintel (2006) and Haskel & Wallis (2013) find a positive influence on growth, inquiring whether publicly-financed R&D influences private sector productivity growth.

While Khan & Luintel study 16 Organisation for Economic Cooperation and Development (OECD) countries and highlight the importance of adding interactions between variables to obtain positive impacts on growth, Haskel & Wallis analyse the effect of different categories of government R&D on TPF growth in the United Kingdom. They point to a significant correlation between R&D and TFP growth, performed specifically through research councils. Conversely, overall public R&D investment does not have a robust relationship with TFP growth.

Also for OECD countries, Soete *et al.* (2021) investigate the relationships between total factor productivity and public and private R&D for 17 countries (1975-2014), through a vector error correction model. The findings indicate that investment in public R&D had a positive impact on TFP growth in most of the samples examined. The authors emphasise the presence of robust complementarity between public and private R&D stocks is an important aspect to explain these results.

3. Data

The share of Gross Fixed Capital Formation in GDP has shown a pendular movement throughout history (Figure 1). After the great depression of the 1930s, government intervention in the economy gained notoriety in many countries, especially the United States (Hannsgen & Papadimitriou, 2009; Perry & Vernengo, 2014; Leff Yaffe, 2020). Nonetheless, from the 1960s, with the renewal of monetarism, there was a reassessment of the government's role in the economy, in the face of criticisms, such as the crowding-out effect on private investment, decreasing the beneficial effect on GDP.

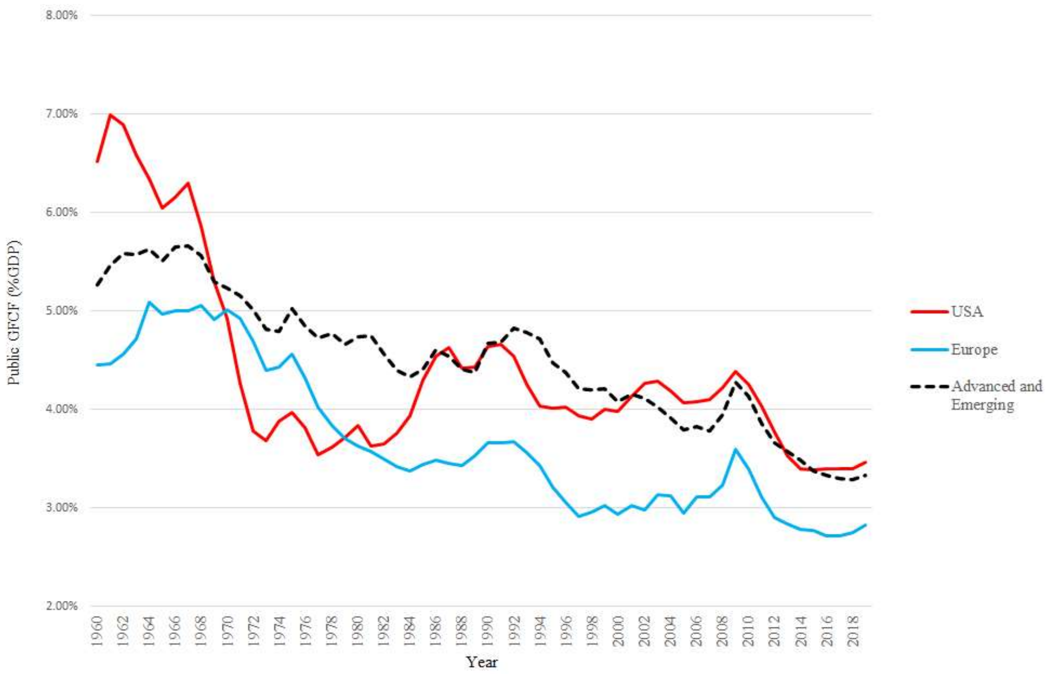

Figure 1. Public Gross Fixed Capital Formation (% of GDP).

Note: The world sample has 30 countries (emerging and advanced) and the European sample has 16 countries. Source: IMF.

Specifically, our study analyses 40 countries, of which 27 are advanced economies and 13 are emerging[2]. The sample covers the period from 1995 to 2019 for gross fixed capital formation of general government (government investment), gross fixed capital formation of private sectors (private investment), and GDP. They are in billions of constant 2017 international dollars. Table 1 presents the country averages for the three variables.

The time series are available from the International Monetary Fund (IMF) and the World Bank (WB). Data for public investment in construction and R&D were obtained from national statistic institutes or central banks in each country (Tables 2 and 3).

[2] According to the IMF definition.

Table 1. Sample Average (1995-2019), billions of constant 2017 dollars and % of GDP.

id	Country	Gov. Investment	Priv. Investment	GDP	Gov. Investment (% of GDP)	Priv. Investment (% of GDP)
1	Argentina	15.81	68.43	825.61	1.9%	8.3%
2	Australia	28.75	200.73	942.62	3.0%	21.3%
3	Austria	12.24	84.81	412.92	3.0%	20.5%
4	Belgium	10.93	98.28	494.32	2.2%	19.9%
5	Brazil	101.46	359.80	2501.70	4.1%	14.4%
6	Canada	55.23	278.86	1457.25	3.8%	19.1%
7	Chile	7.93	60.24	311.45	2.5%	19.3%
8	Colombia	13.86	78.59	501.34	2.8%	15.7%
9	Denmark	9.03	46.75	279.08	3.2%	16.8%
10	Finland	9.25	43.31	229.16	4.0%	18.9%
11	France	103.89	480.85	2637.77	3.9%	18.2%
12	Germany	85.43	692.71	3794.03	2.3%	18.3%
13	Greece	13.12	41.92	333.69	3.9%	12.6%
14	Hong Kong SAR	14.52	59.00	269.06	5.4%	21.9%
15	Hungary	9.27	42.04	237.49	3.9%	17.7%
16	Iceland	0.53	2.48	14.29	3.7%	17.4%
17	India	266.90	840.70	4737.09	5.6%	17.7%
18	Indonesia	59.24	469.63	1822.86	3.3%	25.8%
19	Ireland	6.92	56.66	245.26	2.8%	23.1%
20	Israel	5.81	42.76	245.98	2.4%	17.4%
21	Italy	68.11	409.21	2472.11	2.8%	16.6%
22	Japan	310.52	905.57	4768.47	6.5%	19.0%
23	Korea	79.33	386.26	1505.80	5.3%	25.7%
24	Luxembourg	1.90	7.08	50.91	3.7%	13.9%
25	Malaysia	45.99	75.09	490.41	9.4%	15.3%
26	Mexico	62.84	281.92	1893.99	3.3%	14.9%
27	Netherlands	31.03	133.85	820.22	3.8%	16.3%
28	New Zealand	7.69	24.44	152.83	5.0%	16.0%
29	Norway	13.06	52.19	288.52	4.5%	18.1%
30	Peru	10.20	39.01	249.65	4.1%	15.6%
31	Portugal	10.69	53.12	318.67	3.4%	16.7%
32	Singapore	14.88	65.83	301.28	4.9%	21.8%
33	Spain	51.76	288.37	1602.38	3.2%	18.0%
34	Sweden	17.96	78.63	421.84	4.3%	18.6%
35	Switzerland	15.01	108.21	487.20	3.1%	22.2%
36	Thailand	49.09	134.19	840.90	5.8%	16.0%
37	Turkey	49.36	333.00	1430.23	3.5%	23.3%
38	United Kingdom	63.34	381.66	2558.76	2.5%	14.9%
39	United States	625.63	2608.88	16148.91	3.9%	16.2%
40	South Africa	13.74	72.68	579.96	2.4%	12.5%

Source: IMF and the WB (World Development Indicators).

Table 2. Sample Average (1995-2019) % of GDP. Emerging and Advanced Countries.

Countries	Gov. Investment (Construction) % of GDP
Argentina	1.5%
Brazil	1.2%
Chile	1.5%
Hungary	2.7%
Mexico	1.6%
India	0.2%
Denmark	2.2%
France	2.4%
Germany	1.3%
Italy	1.6%
Netherlands	0.7%
Switzerland	1.6%

Source: Central Banks and National Statistics Institutes.

Table 3. Sample Average (1995-2019) % of GDP. Emerging and Advanced Countries.

Countries	Gov. Investment (R&D) % of GDP
Colombia	0.03%
Hungary	0.23%
Mexico	0.03%
India	0.01%
Denmark	0.80%
France	0.77%
Italy	0.47%
Korea	0.49%
Netherlands	0.48%
Singapore	0.44%

Source: Central Banks and National Statistics Institutes.

The variables were converted into per capita terms (pc) and, later, into diff log series for the use of econometric models. Figures A.1, A.2 and A.3 depict the series.

4. Estimation Strategy

Our investigation is based on three sets of models. First, we assess the effect of the change in public investment on GDP growth and on private investment in a panel with 40 countries, using a PVAR model. Second, we split the sample into two groups and evaluate the impact of public investment on emerging and advanced countries. Lastly, we investigate the effects of public investment in construction and R&D for emerging and advanced economies.

Next, we present the PVAR model (order p) using 40 countries over a period of 25 years (1995-2019):

$$\mathbf{Y}_{it} = \mathbf{B}_1\mathbf{Y}_{\mathbf{it-1}} + \cdots + \mathbf{B}_{p-1}\mathbf{Y}_{it-p+} \; + \mathbf{B}_p\mathbf{Y}_{it-p} + \mathbf{C}\mathbf{X}_{it} + \mathbf{u}_i + \mathbf{e}_{it}, \quad i \in \{1,2,\dots,40\}, t \in \{1,2,\dots,25\} \tag{1}$$

where $\mathbf{Y_{it}}$ is the vector of endogenous variables, $\mathbf{X_{it}}$ is a vector of exogenous variables, **B** is the matrix of autoregressive coefficients, **C** is the matrix of coefficients for the exogenous variables, $\mathbf{u}_i$ is the matrix of country-specific fixed effects, and $\mathbf{e_{it}}$ is the vector of random disturbances. The linear coefficients of each country can be correlated with the error term, leading to biased estimates. To overcome this obstacle, we performed a transformation in the model to eliminate the fixed effects of each economy, through the GMM approach, adding instruments to the PVAR model with lagged data.

The choice of the GMM approach seeks to improve the quality of the dynamic estimators, compared to static estimators, especially when we identify a correlation between the independent variables and the error term. The literature highlights two techniques for transformation in dynamic models, that is, first differences transformation (FD), proposed by Arellano & Bond (1991) and forward orthogonal deviations (FOD) presented by Arellano & Bover (1995).

According to Roodman (2009) and Phillips (2019), the two different transformations can lead to the same GMM estimator. However, the simulations indicate that the estimators obtained by FOD have properties superior to FD, especially when there are gaps in the series because FOD maximises the sample size.

A key issue in the specification and evaluation of VAR models is the definition of the order and the effects of a variable on the others. Briefly, the identification of shocks to government investment that are not contemporaneously correlated with shocks to private investment and GDP. From the econometric perspective, we assume that the institutions responsible for the public budget define investment based on past information from the private sector and economic performance. This assumption is in line with the Cholesky decomposition, admitting that innovations in government investment affect the variables of the model contemporaneously, but the reverse is not the case. Therefore, it seems reasonable that private investment reacts within a year to government investment shocks, but the government cannot reassess and change public investment decisions in less than a year.

We implement the preliminary tests (unit root and the optimal number of lags) and find that our time series are stationary (see the Appendix). In line with Abrigo & Love (2016), we use FOD to remove the individual fixed effects. To identify shocks, we impose a restriction (Cholesky) on the variance-covariance structure of the residues and establish the contemporary effects among the variables.

The series of the first two sets of models have no gaps and the panels are balanced. However, the models that analyse government construction and R&D have shorter time series and gaps. In this case, FOD transformation has an advantage by optimising the sample. The variables (in per capita terms) are the growth rates of government investment (*dlig*), private investment (*dlip*), and GDP (*dlgdp*). They are ordered as follows: *dlig*, *dlip*, *dlgdp*. Lastly, government investment in construction and R&D are represented by *dligctr* and *dligrd*, respectively.

After transforming the original variables into diff-log series, we calculate the government investment multipliers (M_{IG}). The multiplier is defined as the ratio between the elasticity of output with respect to public investment (E_{IG}) and the share of public investment in GDP (Resende & Pires, 2021), as follows:

$$M_{IG} = \frac{E_{IG}}{IG/_{GDP}}. \tag{2}$$

Following Afonso & St. Aubyn (2009), E_{IG} is represented by the ratio between the accumulated change in the growth rate of GDP and the accumulated change in the growth rate of government investment, obtained from the impulse response functions (IRF),

$$E_{IG} = \frac{\Delta\log(GDP)}{\Delta\log(IG)}. \tag{3}$$

5. Results and Discussion

To assess the effects of government investment on private investment and economic performance, three sets of models are presented[3]. The first examines the impact of public

[3] All models are stable and use lagged variables as instruments. The information criteria indicate the lag equal to one.

investment on GDP and on private investment. The second set deepens the analysis, and we verify whether the level of economic development affects the outcome of public investment innovations. In addition, we assess whether there is a crowding-in or crowding-out effect of public investment on private sector investment. Finally, we examine whether the effects of public investment in construction and in R&D differ between emerging and advanced countries.

Based on impulse response functions and investment-to-GDP ratios, we have computed different fiscal multipliers, i.e., overall public investment, public construction investment and public R&D investment. Moreover, the multipliers are presented for the full sample, and for advanced and emerging economies.

An inspection of the IRFs indicates that a shock in government investment has a positive and significant effect on GDP and private investment. Maximum values occur at impact for GDP and in the second year for private investment, followed by a downward movement and then returning to the equilibrium value (Figure 2). In addition, there are indications that public investment fosters private sector investment (crowding-in effect).

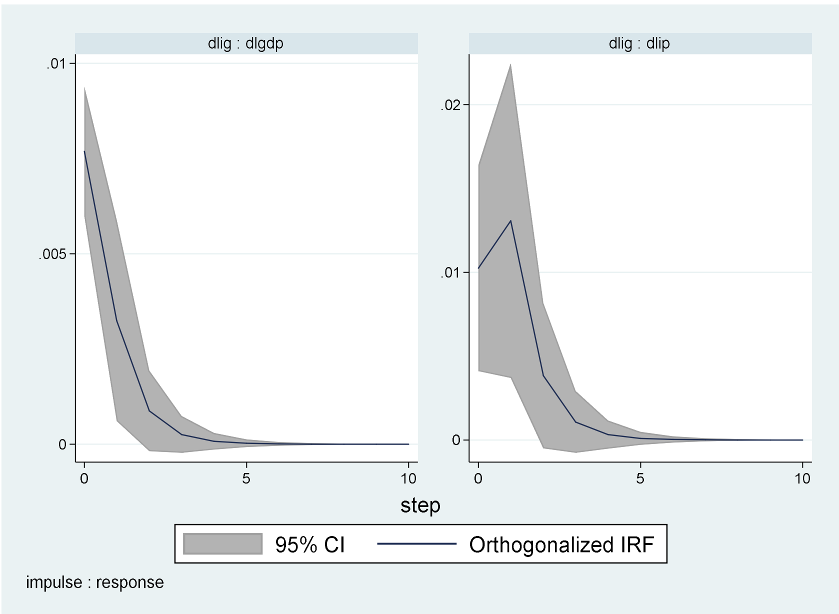

Figure 2: IRF – Effect of Public Investment (40 countries), on GDP and on private investment.

Source: authors' calculations.

To investigate whether government investment produces similar effects in advanced and emerging countries, we split the sample into two groups. Figures 3 and 4 highlight that innovations in public investment stimulate economic growth, regardless of the degree of development. However, this result is only qualitative, as the effect in the sample of emerging economies is significantly more intense.

Additionally, the dynamics of the government investment shock is different when controlling for the degree of development. In this sense, fiscal stimulus (investment) in advanced economies initially discourages the private sector, indicating a crowding-out effect of private investment.

On the other hand, an increase in public investment seems to foster private investment, encouraging new projects, in the sub-sample of emerging economies. This result is in line with the assumption that public investment creates more favourable conditions for new ventures, whether through better infrastructure and reduction of fixed costs or by increasing citizens' confidence or reducing uncertainty about the future of the economy (Gbohoui, 2021).

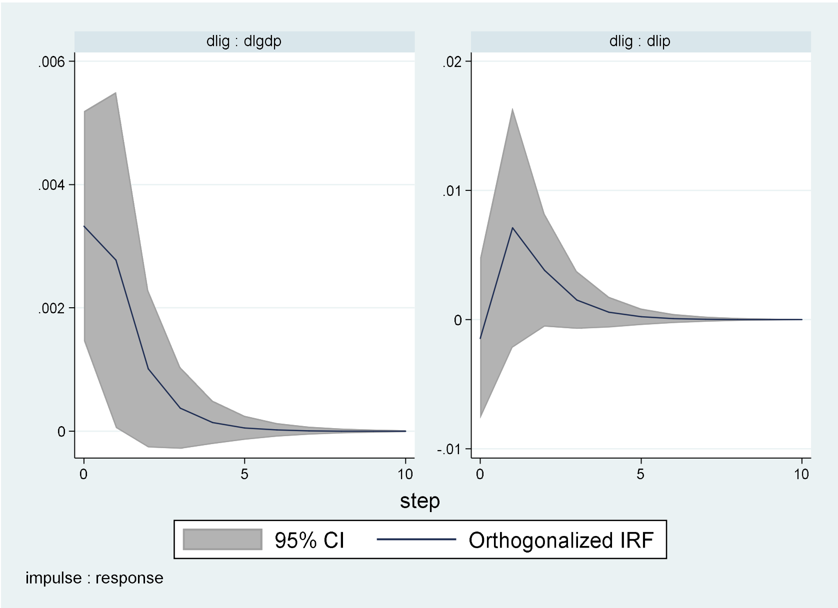

Figure 3: IRF – Effect of Public Investment, on GDP and on private investment (Advanced Economies).

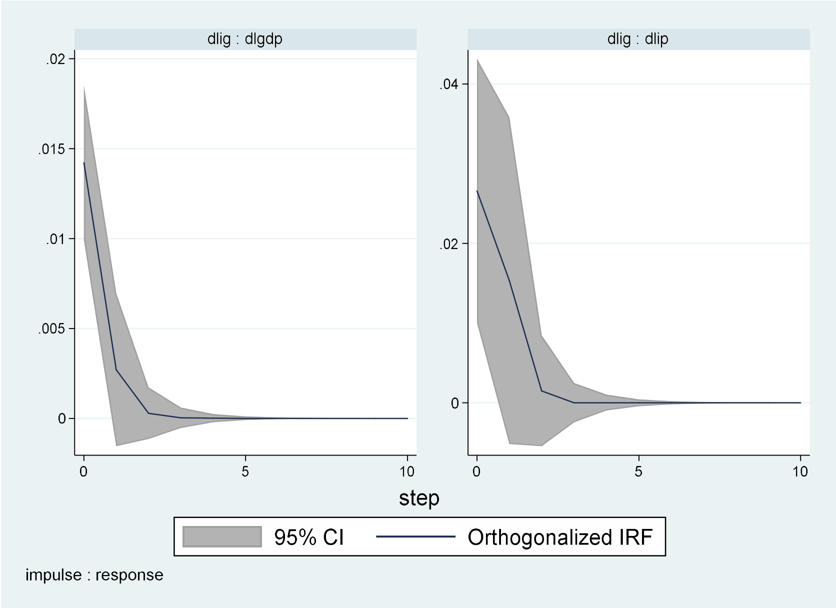

Figure 4: IRF – Effect of Public Investment, on GDP and on private investment (Emerging Economies).

Source: authors' calculations.

Lastly, we estimate the public investment multipliers. Figure 12 highlights the impact multipliers of the fiscal stimulus on the economic system. Thus, we identified that while the multiplier of the full sample is equal to 1.67, advanced economies show a more subtle effect (0.87) than that observed in emerging economies (2.19).

Public Investment (Construction)

An aspect highlighted previously is that public investment can play a relevant role in infrastructure and transport, reducing fixed costs and creating a stable and favourable environment for the private sector. To verify this hypothesis, we select twelve countries (six advanced and emerging countries) and examine the effects produced by the increase in public investments in construction.

Figures 5, 6 and 7 emphasise the differences between the two groups and confirm the patterns verified. First, public investment drives economic growth with greater significance and intensity in emerging countries, in line with previous findings. Second, government investment has a positive impact only on the sample of emerging countries. Due to the scarcity of information and data gaps, the results are positive and significant with a confidence interval of 70% (Figure 7).

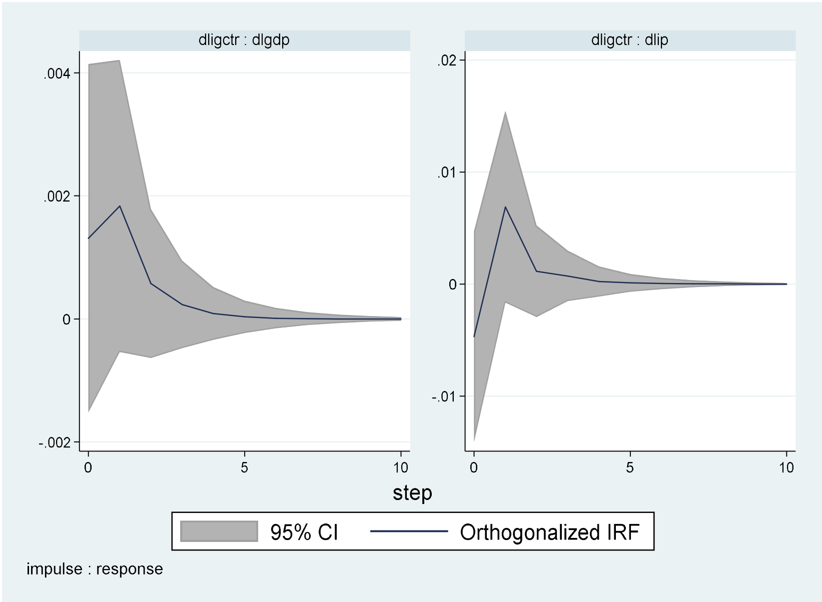

Figure 5: IRF – Effect of Public Investment in Construction, on GDP and on private investment (Six Advanced Economies).

Source: authors' calculations.

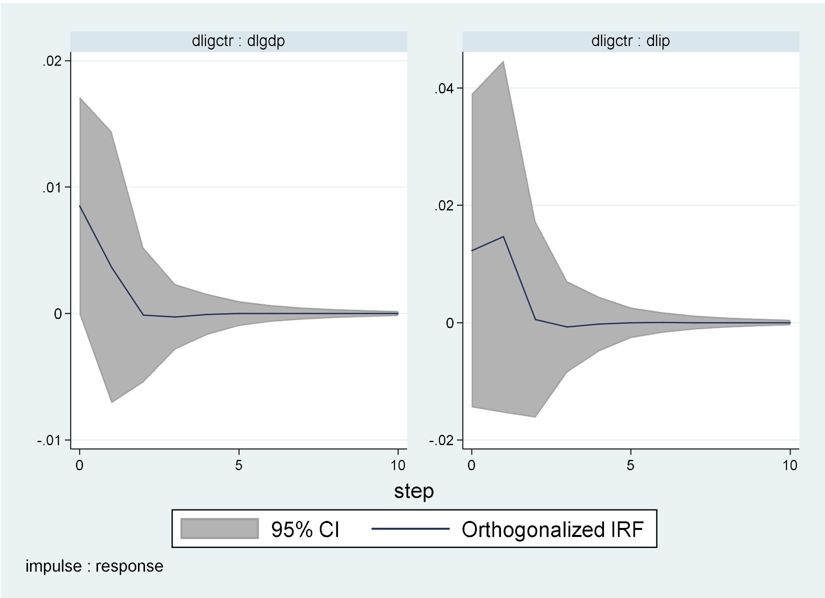

Figure 6: IRF (95% confidence interval) – Effect of Public Investment in Construction, on GDP and on private investment (Six Emerging Economies).

Source: authors' calculations.

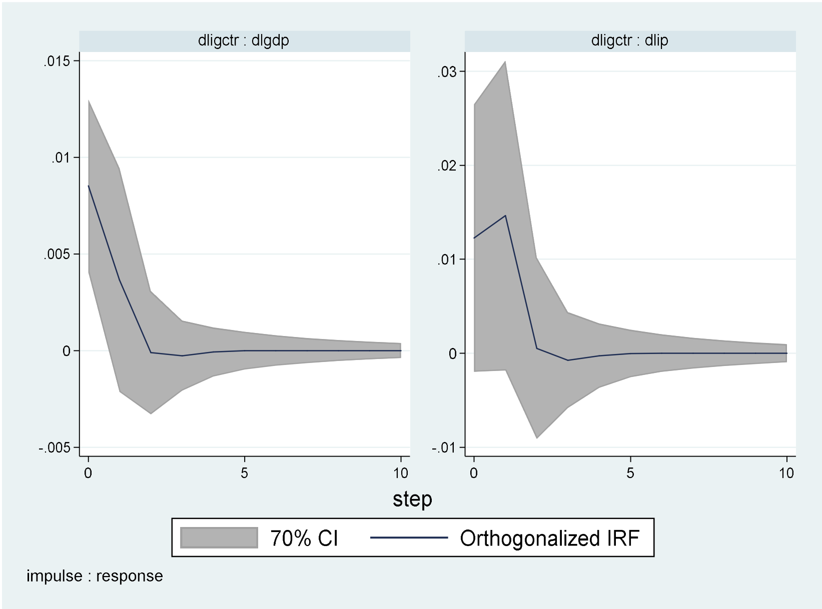

Figure 7: IRF (70% confidence interval) – Effect of Public Investment in Construction, on GDP and on private investment (Six Emerging Economies).
Source: authors' calculations.

Figure 12, in addition to presenting the impact multipliers, suggests that the category of public investment matters. In short, the impact of government investment projects not only confirms the positive effect of overall public investment on GDP but strengthens the relevance of government intervention in the development and maintenance of buildings in emerging economies to stimulate the private sector and growth. These results are in line with the hypothesis that the reduction of fixed costs encourages and attracts new ventures (Gbohoui, 2021), especially in segments where there is still no mature infrastructure.

A central aspect of the result obtained is that an increase in government investment can, directly and indirectly, boost output. Aschauer (1989a) explains that an increase in public capital initially has a direct impact, for example, improving infrastructure conditions and transport networks. This effect works as an increase in total factor productivity, raising output, given the level of private inputs. However, there is an indirect effect that raises the marginal products of labour and private capital, leading to a growth in the level of employment and encouraging private investment.

Public Investment (R&D)

In this subsection, we deepen the analysis and examine the relationship between public investment in R&D and economic growth. In addition, we examine the effect of government R&D innovations on private investment. As in previous experiments, we evaluated the effects on advanced and emerging economies.

Our findings indicate that R&D performed by the government does not automatically foster GDP growth. The estimated IRFs for R&D investments are plotted in the following figures. Our sets of models suggest that, for this sample of advanced countries, public R&D investment does not promote economic growth (Figures 8 and 9). Indeed, the impact is negative and statistically significant with a confidence interval of 75%. Similarly, the effect on private investment is negative.

This finding suggests the presence of rivalry between the public and private sectors. Our results also show that the relationship between private and public investments may be more complex, indicating that it is highly country-specific. Analogously, Van Elk *et al*. (2019) point out that economic returns from government R&D seem to depend on the specific national context. The authors also find negative results and argue that only models that consider the heterogeneity of economies produce positive and significant effects.

In this respect, Khan & Luintel (2006) highlight the importance of interactions between variables to capture the context of each country, as the effects of R&D may depend on the policies of each government. In this way, the authors increase the realism of the results and can estimate positive effects on growth.

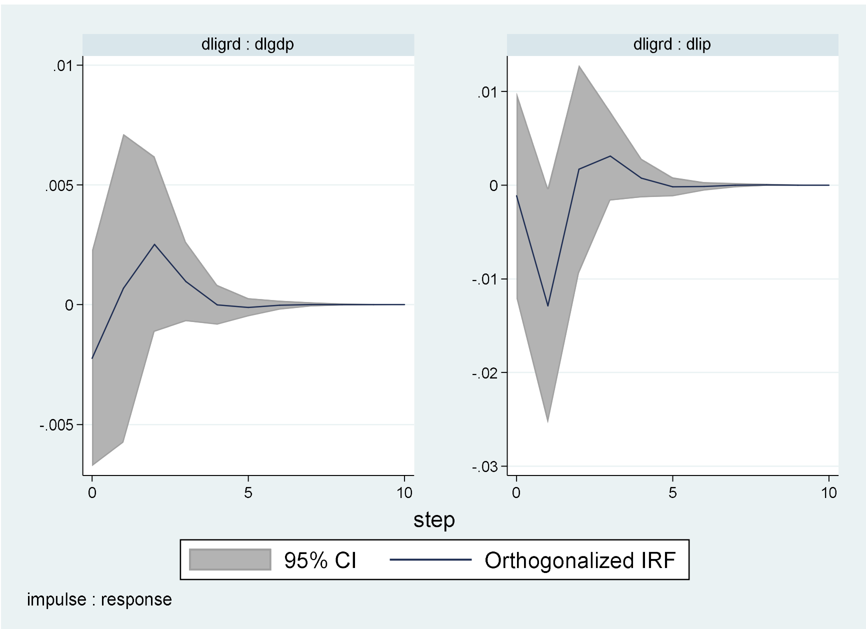

Figure 8: IRF (95% confidence interval) – Effect of Public Investment in R&D, on GDP and on private investment (Six Advanced Economies).
Source: authors' calculations.

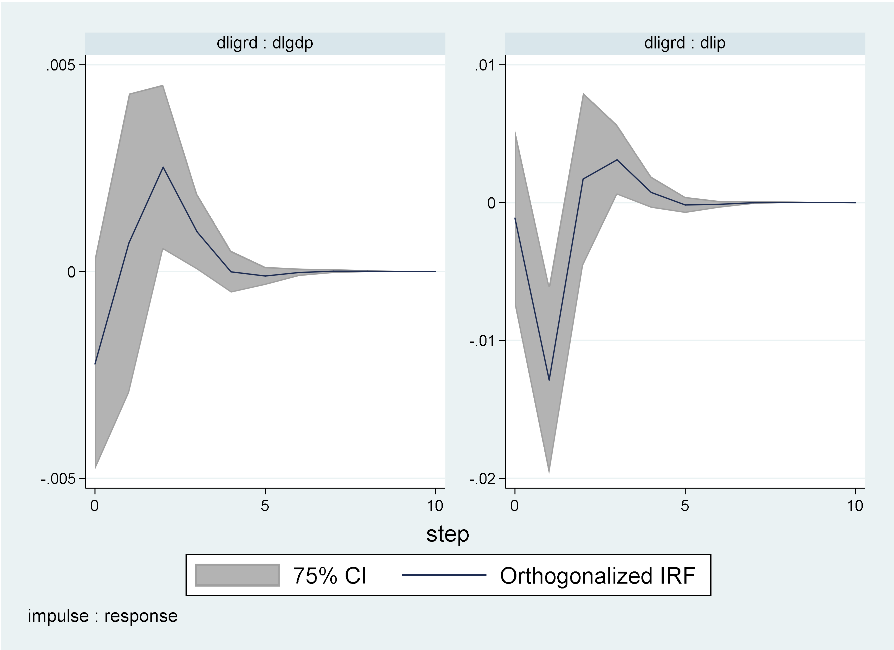

Figure 9: IRF (75% confidence interval) – Effect of Public Investment in R&D, on GDP and on private investment (Six Advanced Economies).
Source: authors' calculations.

Looking at emerging economies, this group tends to perform better in terms of economic growth than advanced countries, despite not having a statistically significant impact. On the other hand, this group reports that an increase in public R&D promotes a significant and positive effect on private investment (Figures 10 and 11). Despite the heterogeneity of countries, our models seem to capture the complementarity between the public and private sectors. These results are highlighted in the multipliers depicted in Figure 12.

As we noted earlier, the results are important and point to a significant difference between the country groups. However, they need to be interpreted carefully. In this sense, the non-significant findings do not necessarily imply that public investments have not promoted economic development, given that the models are limited to economic indicators.

Therefore, the contribution of R&D is broader and generates spillovers that are difficult to capture by models. For example, medical research efforts during the Covid-19 outbreak may not have had an immediate effect on economic performance, but they certainly contribute to mitigating the effects of this and possibly other diseases.

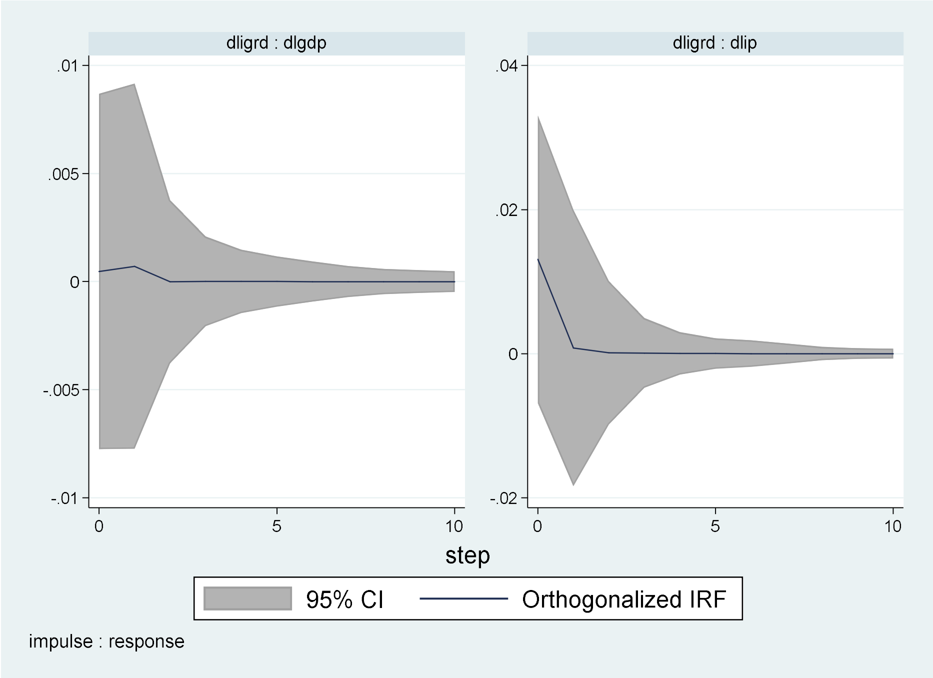

Figure 10: IRF (95% confidence interval) – Effect of Public Investment in R&D, on GDP and on private investment (Four Emerging Economies).
Source: authors' calculations.

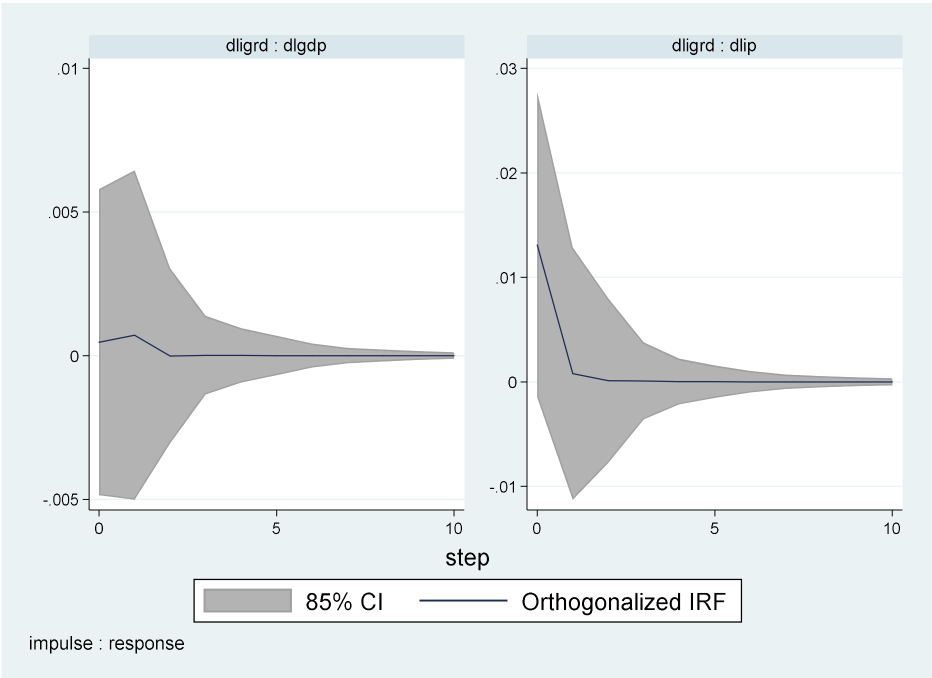

Figure 11: IRF (85% confidence interval) – Effect of Public Investment in R&D, on GDP and on private investment (Four Emerging Economies).
Source: authors' calculations.

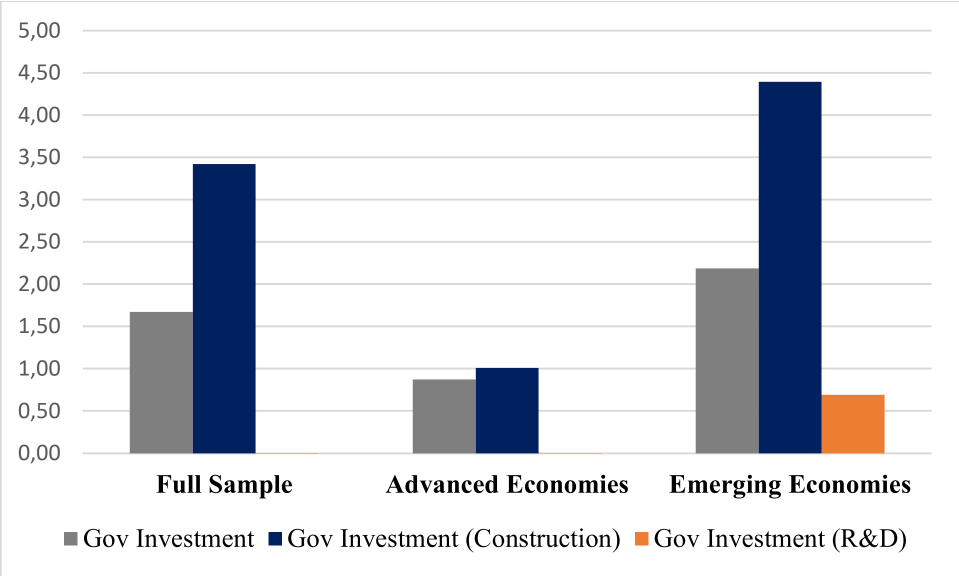

Figure 12: Fiscal Multipliers (Impact) - Public Investment (Global, Construction and R&D).

Source: authors' calculations.

6. Conclusion

We have studied the impacts of public investment, notably in construction and R&D on economic growth and of crowding-out effects on private investment. For this purpose, we use Panel Vector Autoregression (PVAR) models and the Generalised Method of Moments (GMM) approach for 40 advanced and emerging countries from 1995 to 2019. Our findings suggest that innovations in public investment have more positive effects on GDP growth in emerging economies.

Moreover, the positive impulse of public investment on the private sector is pronounced and significant in emerging economies. This can be linked to the possibility that emerging economies still lack some relevant infrastructures, and the macroeconomic rates of return of public investment are then higher in those cases. We also find that government construction investment has a more positive effect on economic growth in emerging economies, and innovations in public construction crowd-out private investment spending in advanced countries.

In addition, we have estimate the public investment multipliers, and we find that the multiplier of the full sample is equal to 1.67, while advanced economies show a more subtle effect (0.87) than that observed in emerging economies (2.19).

Lastly, our results underline that public R&D investment generates quite different effects, depending on the level of economic development. In this sense, public investment has a negative impact on GDP and on the private investment of advanced countries. However, emerging economies benefit from government intervention.

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Appendix

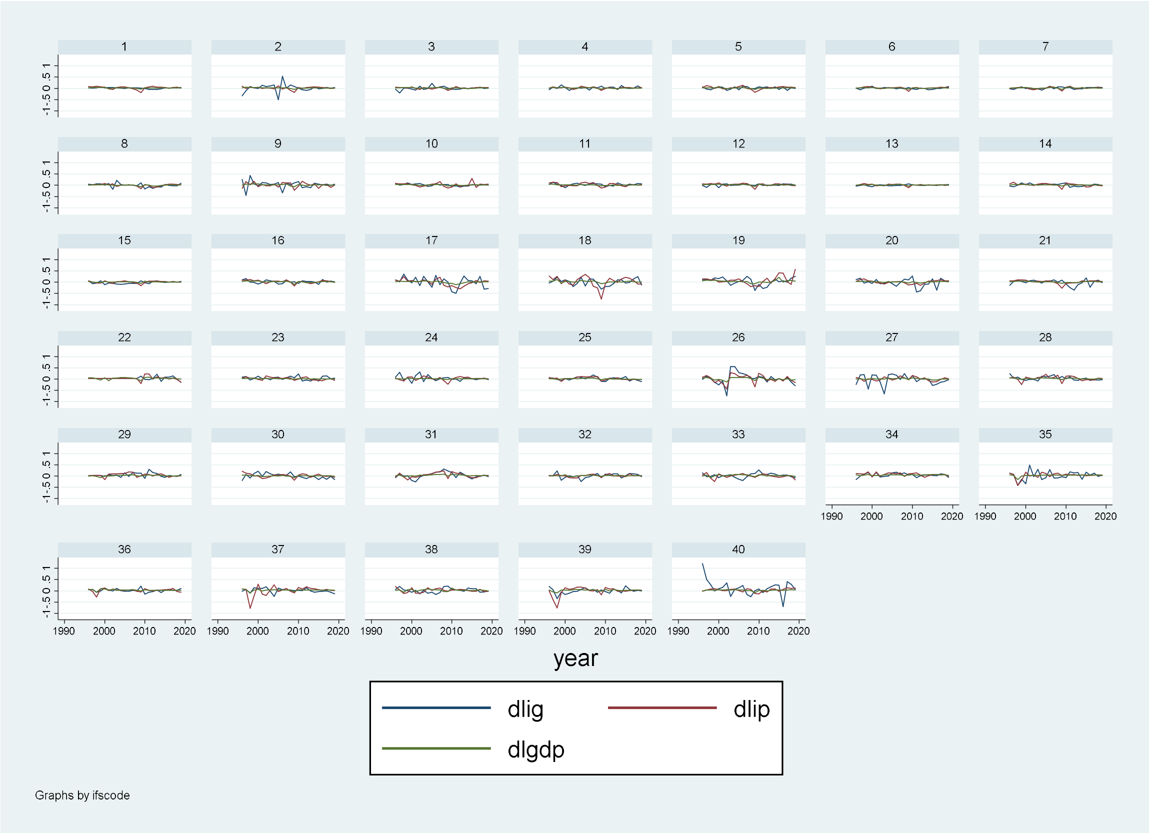

Figure A.1. Series in diff-Log (per capita). Government Investment (dlig), Private Investment (dlip) and GDP (dlgdp).

Source: IMF and the WB (World Development Indicators).

Figure A.2. Series in diff-Log (per capita). Government Investment in Construction (dligctr).

Source: Central Banks and National Statistics Institutes.

Figure A.3. Series in diff-Log (per capita). Government Investment in R&D (dligrd). Source: Central Banks and National Statistics Institutes.

Unit root tests

For the series associated with the effects of government investment (total and construction), the Harris-Tzavalis test was used. For the series associated with government investments in R&D, we used the Im–Pesaran–Shin test, which allows for unbalanced panels. We find evidence against the null hypothesis of a unit root and therefore conclude that the series are stationary.

Table A.1. Unit Roots: Full sample.

		Statistic	**z**	**P-Value**
dlig	rho	0.0491	-42.1090	0.0000
dlip	rho	0.255	-31.675	0.0000
dlgdp	rho	0.239	-32.485	0.0000

Source: authors' calculations.

Table A.2. Unit Roots: Advanced Economies.

		Statistic	z	P-Value
dlig	rho	0.0091	-36.2611	0.0000
dlip	rho	0.3174	-23.4227	0.0000
dlgdp	rho	0.2743	-25.2171	0.0000

Source: authors' calculations.

Table A.3. Unit Roots: Emerging Economies.

		Statistic	z	P-Value
dlig	rho	0.0793	-22.2260	0.0000
dlip	rho	0.1853	-19.2832	0.0000
dlgdp	rho	0.1857	-19.2728	0.0000

Source: authors' calculations.

Table A.4. Series associated with Gov. Investment in Construction (Advanced Economies).

		Statistic	z	P-Value
dligctr	rho	-1048	-19.3291	0.0000
dlip	rho	0.1725	-13.8870	0.0000
dlgdp	rho	0.2756	-11.8621	0.0000

Source: authors' calculations.

Table A.5. Series associated with Gov. Investment in Construction (Emerging Economies).

		Statistic	z	P-Value
dligctr	rho	0.0968	-15.3722	0.0000
dlip	rho	0.0941	-15.4252	0.0000
dlgdp	rho	0.2517	-12.3322	0.0000

Source: authors' calculations.

Table A.6. Unit Roots: Series associated with Gov. Investment in R&D (Advanced Economies).

		Statistic	P-Value
dligrd	t-bar	-4.2560	
	t-tilde-bar	-3.0949	
	Z-t-tilde-bar	-5.7231	0.0000
dlip	t-bar	-3.9611	
	t-tilde-bar	-3.0087	
	Z-t-tilde-bar	-5.4298	0.0000
dlgdp	t-bar	-3.9487	
	t-tilde-bar	-2.9786	
	Z-t-tilde-bar	-5.3272	0.0000

Source: authors' calculations.

Table A.7. Unit Roots: Series for Gov. Investment in R&D (Emerging Economies).

		Statistic	P-Value
dligrd	t-bar	-3.6342	
	t-tilde-bar	-2.5299	
	Z-t-tilde-bar	-3.2509	0.0000
dlip	t-bar	-3.7716	
	t-tilde-bar	-2.8832	
	Z-t-tilde-bar	-3.7922	0.0000
dlgdp	t-bar	-3.4749	
	t-tilde-bar	-2.7647	
	Z-t-tilde-bar	-3.4869	0.0000

Source: authors' calculations.

Eigenvalue Stability Condition

Next, we present the results of post-estimation analysis. This examination checks the stability condition of PVAR estimates by calculating the modulus of each eigenvalue of the fitted model. Therefore, they show that a model is stable if all moduli of the companion matrix are strictly less than one.

Table A.8. Stability Condition: Full sample (Public Investment - Total).

Eigenvalue		
Real	Imaginary	Modulus
.2916604	0	0.291660
-.0237577	-.0608546	0.065328
-.0237577	.0608546	0.065328

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.9. Stability Condition: Advanced Economies (Public Investment - Total).

Eigenvalue		
Real	Imaginary	Modulus
.3825351	0	0.3825351
.0404139	.0533781	0.0669515
.0404139	-.0533781	0.0669515

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.10. Stability Condition: Emerging Economies (Public Investment - Total).

Eigenvalue		
Real	Imaginary	Modulus
-.0702192	-.1221574	0.1409012
-.0702192	.1221574	0.1409012
.1278614	0	0.1278614

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.11. Stability Condition: Advanced Economies (Public Investment - Construction).

Eigenvalue		
Real	Imaginary	Modulus
.4069728	0	0.4069728
-.2104217	0	-0.2104217
-.0170353	0	-0.0170353

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.12. Stability Condition: Emerging Economies (Public Investment - Construction).

Eigenvalue		
Real	Imaginary	Modulus
.2339607	0	0.2339607
-.0621687	.2040191	0.2132809
-.0621687	.2040192	0.2132809

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.13. Stability Condition: Advanced Economies (Public Investment – R&D).

Eigenvalue		
Real	Imaginary	Modulus
.1218692	-.3413898	0.362490
.1218692	.3413898	0.362490
.212029	0	0.212029

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.

Table A.14. Stability Condition: Emerging Economies (Public Investment – R&D).

Eigenvalue		
Real	Imaginary	Modulus
.3380031	0	0.338003
-.0426609	.0985101	0.107351
-.0426609	-.0985101	0.107351

All the eigenvalues lie inside the unit circle. PVAR satisfies stability condition.

Source: authors' calculations.