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Macroeconomic Effects of Public Investment in EMDEs: Nonlinear Effects of the Business Cycle, Fiscal Space, Capital Stock and Efficiency

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ABSTRACT

The paper examines the macroeconomic effects of public investment in emerging market and developing economies (EMDEs). To this end the analysis develops a new measure of public investment shocks based on cyclically adjusted government investment. Estimations using local projections based on a sample of 129 countries over the period 1980–2019 suggest that public investment can significantly boost economic growth, crowd in private investment, and increase productivity and potential output. Estimates suggest that an increase in public investment by 1% of GDP raises real output by 1.1% after 5 years, on average. However, the effects are much larger when public investment spending is efficient and fiscal space is ample—reaching up to 1.6% over the same period. Public investment multipliers tend to be larger during recessions and in capital scarce economies.

JEL Classification: C33, E22, E26, E62, H30, H50

1 | Introduction

Public investment can be a powerful lever for growth, especially in emerging market and developing economies (EMDEs) with large infrastructure gaps and slowing private investment [1]. It supports human capital and productivity, facilitates the flow of goods, services, labour, and capital, and can crowd in private investment—addressing goods with non-excludable, non-rival features that the private sector undersupplies. Yet the net positive macroeconomic effects are not guaranteed: projects are costly and can raise deficits and debt when their planning and execution are weak, while spending is inefficient [2–4]. Governance failures—corruption, poor monitoring, and weak accountability—can produce unproductive 'white elephant' projects [5–7] and, in some settings, crowd out private investment [8, 9].

Unsurprisingly, estimated public investment multipliers vary widely by country sample, period, method, and non-linearities [10–12]. A key empirical challenge is identifying spending changes orthogonal to contemporaneous shocks. Evidence focused on EMDEs remains relatively scarce, reflecting data and identification constraints, compared with studies of advanced economies or total public spending.

This paper contributes to the literature in four ways. First, we assemble data for 129 EMDEs over the period 1980–2019, enabling robust estimates for EMDEs as a whole and

comparisons across heterogeneous groups—for instance, low-income countries and commodity exporters. Second, we incorporate recent advances on initial conditions and structural features, estimating state-dependent multipliers by business-cycle position, initial public capital, fiscal space, and public investment efficiency, using a smooth-transition local projection (LP-STAR) approach to capture non-linearities. Third, we develop a new shock measure that identifies country-specific, one-off, large changes in cyclically adjusted government investment from publicly accessible annual data—replicable across countries and not restricted to specific spending types, for instance, military spending or official development assistance (ODA) disbursements. We validate this identification with extensive robustness checks (including Granger non-causality, augmented inverse probability weighted estimations, IV in LP-2SLS, and sensitivity to the choice of statistical filters and thresholds). While not universally superior, the method is transparent and scalable for large cross-country applications. Fourth, we document supply-side effects in EMDEs, examining private investment, productivity, and potential output alongside unconditional and state-dependent multipliers.

Our local-projection estimates using identified shocks indicate that in EMDEs, a 1% of GDP increase in public investment raises output by about 1.1% after 5 years, on average. Effects are larger and statistically stronger when investment efficiency is higher or fiscal space is ample—up to 1.6% over 5 years. By contrast, the effects are smaller and not statistically significant in countries with low efficiency or constrained fiscal space. Consistent with the literature, multipliers are larger in recessions and in capital-scarce economies. We also find crowding-in of private investment: a 1% of GDP increase in public investment lifts private investment by up to 2.2% over 5 years. On the supply side, public investment raises labour productivity by 1.9%, TFP by 0.8%, and potential output by 1.1% over 5 years, providing empirical support for both short-run demand and long-run growth channels.

The remainder of the paper is organised as follows. Section 2 reviews the literature. Section 3 presents the identification strategy and empirical methodology. Section 4 reports results. Section 5 discusses policy implications and concludes.

2 | Synthesis of the Literature

2.1 | Theoretical Foundations and Transmission Channels

The early literature studies public investment within endogenous-growth frameworks where public capital is a productive input [8, 13–18], later incorporating aid-financed investment, networked infrastructure, and debt dynamics to refine transmission mechanisms [4, 19–21]. More recent work emphasises investment quality and corruption [5]. Broadly, the literature identifies four main channels through which public investment affects growth. First, short-run demand: public investment raises aggregate demand, but effects can be offset by financing (taxes, debt, or spending reallocation), import leakages, and potential fiscal imbalances; demand support may also reduce hysteresis, with Kaldor–Verdoorn feedbacks from output to productivity [22–25]. Second, long-run supply: infrastructure expands capacity and private-factor productivity, though network externalities imply diminishing returns once core networks are in place [26]; in low-income countries, higher initial capital can sometimes amplify responses [27]. Third, private investment: crowding-in arises via higher returns and risk-sharing (e.g., PPPs), but crowding-out can occur when fiscal space is tight and sovereign risk rises [8, 28–30].[1] Fourth, efficiency and maintenance: weak governance and poor project design dilute the translation of spending into productive capital and can create costly 'white elephants', while inadequate maintenance erodes capital services and strains budgets [6, 7, 33]. Finally, public investment's role in non-market public goods (health, education, water, energy, and security) links it to sustainable and inclusive growth via human capital and environmental objectives [34–36].

2.2 | Estimates of Public Investment Multipliers

Empirical work on government spending multipliers is vast, but studies that separate public investment from public consumption remain are scarce and largely examine advanced economies. The emerging view is that public investment has a positive medium-term growth impact and typically yields larger, more persistent multipliers than public consumption [29, 37–41]. Results on scale effects are mixed: our findings on capital scarcity align with diminishing returns on additional public investment [42], whereas Honda et al. [27] show that in low-income countries, higher initial capital can enable larger multipliers through greater response of the private sector. Reflecting methodological and data differences, estimates vary widely: Bom and Ligthart [10] report output elasticities ranging from −1.7 to 2.0 across 68 studies, while survey evidence points to average investment multipliers around 1.5 [11, 12].

Evidence for EMDEs is scarce but also documents non-trivial growth effects of public investment. Thus, Miyamoto et al. [43] find that output rises by about 0.4% over 4 years for a sample of 39 EMDEs following a public investment increase. Ilzetzki et al. [39] estimate an impact multiplier near 0.6, rising to 1.6 in the longer run for 24 developing countries. Furceri and Li [38] obtain somewhat smaller effects for 79 EMDEs—roughly 0.4% over 4 years for a 10% investment increase—while Warner [44], using 124 EMDEs, reports muted short-run effects (about 0.1% for a 1%-of-GDP increase) and no significant long-run response.

Heterogeneity in estimated multipliers reflects both cyclical conditions and structural features. In particular, multipliers tend to be larger in recessions [27, 37, 45–46], especially in supply-driven downturns [47], and when monetary policy is accommodative or constrained at the effective lower bound [48, 49]. On the structural side, higher spending efficiency [9, 38, 40, 41, 43, 50–51] and lower initial public capital [40] are generally associated with larger effects, although excessive capital accumulation can dampen growth [42, 52] and, in low-income countries, very low initial capital may limit private-sector responsiveness [27]. Effects also differ by type of investment—equipment versus construction—especially near the lower bound [53]. Finally, stronger multipliers are more likely under fixed exchange rates,

lower public debt, deeper financial markets, greater trade openness, and lower informality [27, 30, 39, 54–55].

A consolidated summary of estimated public investment multipliers, along with the associated samples and methodologies, is reported in the Table B1.

2.3 | Main Approaches to the Identification of Public Investment Shocks

A central challenge in this literature is to identify exogenous public investment shocks—changes that are orthogonal to prevailing macroeconomic conditions. Existing strategies include SVARs with recursive identification, instrumental-variable designs, narrative proxies, and forecast-error–based shocks. SVAR approaches à la Blanchard and Perotti [56] rely on within-period non-response assumptions (via Cholesky ordering) that are less compelling at annual frequency, while higher-frequency investment data are scarce in EMDEs. Instrumental-variable designs based on official lending [57, 58] exploit the timing of disbursements to isolate a component insulated from contemporaneous conditions but are limited to aid recipients and require constructing loan-level predicted disbursements. Narrative or military-spending instruments [59–63] treat geopolitical news as exogenous; however, this translates poorly to EMDEs—where military outlays are often less variable—and risks identifying the effects of the military subcomponent rather than broad public investment. Forecast-error shocks [37, 45] mitigate fiscal foresight [64–66] by using deviations from professional projections, but they hinge on the availability and quality of forecasts that can be noisy, subjective, and uneven across countries—especially where fiscal dynamics are volatile—raising concerns about orthogonality to past trends.

Against this backdrop, the next section sets out a new framework tailored to public investment and scalable to large EMDE panels. We then apply it to estimate investment multipliers and to examine macroeconomic effects beyond output growth.

3 | Methodology and Data

3.1 | Data and Stylized Facts

The database used in the estimation of the macroeconomic effects of public investment draws from several sources. Public investment, private investment, and capital stock data are from the International Monetary Fund's Investment and Capital Stock Dataset [67]. Public debt data are retrieved from the World Bank's Fiscal Space Database [68]. Public investment efficiency data are obtained from several sources: IMF [69] Fiscal Monitor database, Devadas and Pennings [70], and Dabla-Norris et al. [6]. Potential output data are sourced from Kilic Celik et al. [71], which uses the production function approach to estimate the series. The GDP and inflation series are drawn from the IMF's World Economic Outlook database. Labour productivity and total factor productivity data are from Penn World Table 10.01. Real interest rate data are from the World Bank's WDI and IMF's IFS databases. The resulting dataset comprises up to 129 EMDEs over the period 1980–2019 (see Table A1 for the sample composition). Public investment in the paper refers to general government gross fixed capital formation, and thus, in line with national accounts conventions, government expenditures classified as current spending rather than investment, such as maintenance expenditures or defence spending, are not included in the measure of public investment (see IMF [67] for additional details on the construction of the public investment series). Table A2 provides data definitions and sources of variables.

We begin by highlighting key public investment patterns across EMDEs. Public investment plays a larger role in EMDEs than in advanced economies: over the past decade, it averaged about 7% of GDP versus 4% in advanced economies (Figure 1A), and amounted to nearly 30% of total investment (higher in low-income countries—about 40%)—compared with less than 20% in advanced economies (Figure 1B). This reflects a generally weaker private sector and its limited capacity to finance large investment projects in many EMDEs, as well as the greater creditworthiness of governments, which can tax, collateralize assets, and pool larger resources for infrastructure investment [72].

Public investment in EMDEs has shifted markedly over the past three decades. It rose strongly in the 1990s, driven by China, and surged further in the 2000s amid macroeconomic stability, rapid integration, and high commodity prices—particularly in commodity exporting countries (Figure 1C,D). Since the global financial crisis, however, public investment growth has slowed sharply: dropping from the annual average growth of 10% in the 2000s to just 5% in the 2010s—the weakest pace in three decades (Figure 1C). Multiple factors inhibited investment, including weaker economic growth, sluggish trade and capital flows, rising uncertainty, tighter financial conditions, and elevated debt levels. Commodity-exporting countries were especially hit as revenues declined amid global commodity price shocks and heightened volatility (Figure 1D). The COVID-19 recession further constrained public investment, as many governments prioritised more urgent health measures and social support policy packages, delaying or cutting capital spending.

3.2 | New Approach to Identify Public Investment Shocks Based on Cyclically Adjusted Public Spending

In this paper we apply a new approach to identify public investment shocks as country-specific one-off large changes in cyclically adjusted public investment. More specifically, the shock identification framework involves the following four steps:

1. We estimate output elasticities of public investment for each country in the sample by regressing the logarithm of real public investment on the logarithm of real GDP. Estimates are done using ordinary least squares for each country with at least 20 continuous observations of both variables.[2]
2. For each country in the sample we obtain measures of potential output GDP^{pot} via a Hodrick-Prescott (HP) filter as the baseline estimate, applying the conventional smoothing parameter $\lambda = 100$ for annual data. We also use Baxter-King, Christiano-Fitzgerald Random Walk and the Hamilton [73] filters as a robustness check. Across all cases, the resulting multipliers are statistically similar, indicating

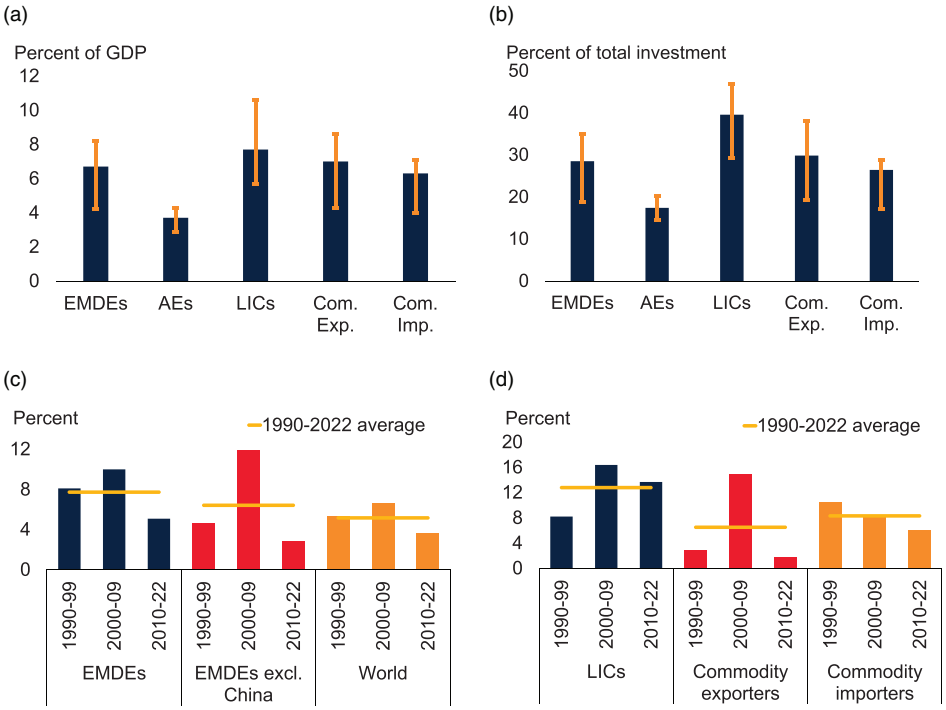

FIGURE 1 | Public investment in EMDEs. (A) Public investment, percent of GDP. (B) Public investment, percent of total investment. (C) Public investment growth. (D) Public investment growth by EMDE group. *Source:* Haver Analytics; IMF Investment and Capital Stock Dataset [67]; WDI (database); World Bank. AEs = advanced economies; EMDEs = emerging market and developing economies; Com. Exp. = commodity-exporting EMDEs; Com. Imp. = commodity-importing EMDEs; LICs = low-income countries. Public investment growth is calculated with countries' real public investment in constant international dollars as weights. A.B. Bars show means and whiskers show interquartile ranges for 2010–22 by group. Sample includes up to 36 advanced economies and 126 EMDEs. C.D. Average annual public investment growth. Sample includes up to 162 economies, of which 126 are EMDEs, 23 are LICs, 76 are commodity-exporting EMDEs, and 50 are commodity-importing EMDEs. [Colour figure can be viewed at wileyonlinelibrary.com]

that our results are not sensitive to the choice of filter for estimating potential output.

3. We compute cyclically adjusted real public investment (*CAPI*) as follows:

$$CAPI = PI\left(\frac{GDP^{pot}}{GDP}\right)^{\epsilon_{PI}} \quad (1)$$

where *PI* is real public investment and ϵ_{PI} is the estimated elasticity of public investment.

4. For each country *i* we define public investment shocks ($shock_{i,t}$) as a measure taking the value of one when a country's first difference of *CAPI* exceeds its country-specific mean by one standard deviation:

$$shock_{i,t} = 1 \; if \; \Delta CAPI_{it} > \overline{\Delta CAPI_i} + SDCAPI_i, 0 \; \text{otherwise} \quad (2)$$

We focus on country-year public investment increases exceeding one standard deviation in the cyclically adjusted series. Large discrete adjustments are more likely to reflect discretionary policy choices rather than automatic co-movements with the business cycle. Descriptive statistics for shock episodes are reported in Table A3.

Conceptually, our approach aligns with the view that large, visible scale-ups of public investment tend to reflect exogenous policy decisions [44, 74]. Nevertheless, we go a step further by purging cyclical co-movements in public investment before identifying public investment shocks and implementing a set of formal diagnostic checks to validate the identification and the robustness of the estimated macroeconomic effects. We deliberately focus on public investment shocks—as opposed to broader fiscal expansions and consolidations—which are often endogenous to the cycle. In practice, large investment projects are often conceived, appraised, and legislated years in advance and embedded in multi-year capital budgets, making their timing less responsive to contemporaneous fluctuations than public consumption. To further ensure orthogonality, we conduct a battery of robustness tests—alternative statistical filters, sensitivity to the choice of thresholds, instrumenting change in the public-investment-to-GDP ratio Δ(*PI/GDP*) with the identified shocks in LP-2SLS estimations, and other exercises that validate our shock identification framework—outlined next and also discussed in the robustness checks section and the Supporting Information.

3.2.1 | Validation of the Shock Measure

We carry out a range of exercises to validate the identified public investment shocks. *As a first validation*, Figure A1 presents the distribution of the country-specific elasticities (ε) obtained from regressing log public investment on log GDP. The distribution

is centred around unity, with a mean of 1.09 and a median of 0.93 across more than 10,000 observations. Most elasticities lie between 0 and 2, while only a few negative or very high values above 3 are observed. This pattern suggests that our shock identification does not rely on implausibly large or systematically biased elasticities.

As a second validation, we benchmark our business-cycle-adjusted shock against a purely mechanical "raw-extreme" indicator that flags years in the top 5% of the global distribution of $|\Delta(PI/GDP)|$. In our estimation sample ($N = 5329$ country-years), the baseline shock identifies 557 episodes (≈10.5%) and the raw-extreme indicator 207 (≈3.9%), with only 1.4% of observations flagged by both. The correlation between the baseline shock and the raw-absolute indicator is 0.15, rising to 0.39 when focusing only on large positive changes. Re-estimating the local projections with the raw-extreme definition yields real GDP responses that are qualitatively similar to the baseline, but somewhat attenuated and less precisely estimated – consistent with raw extremes being noisier and more affected by cyclical co-movement (reported in the Supporting Information). These results reinforce the value of the cyclical adjustment embedded in our shock measure.[3]

As a *third validation*, we assess the orthogonality of the identified public investment shocks to macroeconomic conditions by computing pairwise correlations with real GDP growth at t, $t-1$, $t-2$, $t+1$, and $t+2$, as well as with the output gap. The correlations are uniformly very small in magnitude. Specifically, the correlation between the shock indicator and contemporaneous GDP growth is 0.04, and correlations with lagged growth are close to zero (0.01 at $t-1$ and −0.00 at $t-2$). Forward correlations are also modest (0.04 at $t+1$ and 0.06 at $t+2$). The correlation with the output gap is slightly negative (−0.05). Although several coefficients are statistically significant due to the large sample size, all values are economically negligible, lying between −0.05 and 0.06. These results confirm that the shock measure is not systematically related to recent or future cyclical conditions, reinforcing its orthogonality to short-run macroeconomic dynamics.[4]

As a fourth validation, we re-estimate the local projections for unconditional and state-dependent multipliers using the identified binary shocks as instruments for actual changes in public investment (as a share of GDP) in the two-stage least squares (2SLS) framework. The resulting impulse responses—both unconditional and state-dependent—are virtually identical to the baseline in terms of both magnitudes and statistical significance (short- and medium-term multipliers of about 0.4 and 1.0 after 1 and 5 years, respectively—see Table 1 and Supporting Information: Appendix Section C). This instrumental-variable validation further supports the robustness of the identification and confirms that the binary shock design captures genuine policy-driven public investment impulses rather than noise. Taken together, these diagnostics indicate that the identified shocks are neither driven by nor systematically anticipated by short-run macroeconomic dynamics.

While we do not claim universal superiority of our approach relative to other identification frameworks, this strategy offers a number of advantages. It is transparent and scalable for large cross-country panels; it avoids dependence on non-public data (for instance, forecast errors in public investment); it does not require quarterly series, often unavailable in EMDEs; and it is not restricted to specific spending categories (for instance, military outlays or ODA episodes). As such, the framework can be easily implemented for a broad sample of countries with annual data, and supports estimation of state-dependent multipliers and heterogeneous effects across country groups.

In contrast to one-size-fits-all approaches, our framework also accommodates country heterogeneity by evaluating the magnitude of shocks in their country-specific historical context—an important feature for EMDEs where fiscal policy can be procyclical (e.g., in commodity-exporting countries) or volatile due to budget processes (e.g., in low-income countries). The approach naturally extends to time-varying or state-dependent thresholds.

The focus on large CAPI increases also maps well to policy practice. Large-scale infrastructure undertakings require long lead times, legal approvals, and multi-year commitments; their timing is often shaped by external anchors (e.g., IFI disbursement cycles and ODA tranches) rather than contemporaneous demand conditions. Historical episodes captured by our shock definition—such as Brazil's Growth Acceleration Program (2007), and Morocco's 2008 expansion under the Green Plan and Tanger-Med—were driven by strategic policy choices rather than short-run stabilisation.

We note three caveats. First, residual endogeneity and fiscal foresight cannot be ruled out completely, notwithstanding the large-shock focus and the diagnostic checks above. Second, the methodology relies on potential output estimates, which are inherently imprecise; our robustness exercises using alternative filters mitigate, but do not eliminate, this concern. Third, the shock is a binary indicator; multipliers are therefore obtained by rescaling IRFs using the average $\Delta(PI/GDP)$ observed among shocked observations or by using the shocks as instruments for $\Delta(PI/GDP)$ in LP-2SLS. We implement both approaches for unconditional and state-dependent multipliers.

Besides the validation exercises outlined above, we subject the methodology to a wide set of additional robustness checks (filters, thresholds, sample composition and periods, anticipation/leads, and alternative estimators). Results are stable across these empirical exercises. Details are provided in the robustness section and the Supporting Information.

3.3 | Methodological Framework for the Estimation of Public Investment Multipliers

Responses of real GDP to public investment shocks are estimated using the local projections method proposed by Jordà [75]. This approach has a number of distinct advantages over other estimation frameworks that could potentially be used in the estimation of the macroeconomic effects of public investment, including VAR models. First, it does not impose dynamic restrictions and obviates the need to estimate the equations for dependent variables other than the variable of interest, thereby economising on the number of estimated parameters. Second, it is well-suited to estimating nonlinear effects of public investment conditional on country-characteristics (state-dependent multipliers). Third, it is

TABLE 1 | Selected additional results and robustness checks.

Model	Public investment multiplier	
	$t=1$	$t=5$
Baseline specification	0.4***	1.1***
IV (2SLS) estimation using public investment shocks to instrument public investment	0.4***	1.0***
GMM estimation	0.5**	0.8**
Dropping country fixed effects	0.4***	1.5***
Dropping lagged real GDP growth variable	0.3**	1.1***
Pre-global financial crisis period only (1980–2007)	0.3*	0.9***
Additional control variables: two lags of inflation and trade-to-GDP ratio	0.4**	1.1***
Additional control variables: two lags of real interest rate	0.6***	1.4***
Alternative fiscal space specifications		
Large increase in debt-to-GDP ratio (upper quartile = above 3.7)	0.3	0.7
Large decrease in debt-to-GDP ratio (lower quartile = below −3.2)	0.5*	1.4***
Alternative public investment efficiency measures		
Low efficiency: Dabla-Norris et al. [6] PIMI below the sample mean	0.1	0.9
High efficiency: Dabla-Norris et al. [6] PIMI above the sample mean	0.4***	1.2***
Low efficiency: Bottom quartile of Devadas and Pennings [70] Infrastructure Efficiency index	0.2	0.3
High efficiency: Top quartile of Devadas and Pennings [70] Infrastructure Efficiency index	0.2*	1.0***
Low efficiency: Bottom quartile of CPIA Public Sector Management and Institutions index	0.3	0.6
High efficiency: Top quartile of CPIA Public Sector Management and Institutions index	0.4**	1.1***

Note: 2SLS = two-stage least squares; CPIA = Country Policy and Institutional Assessment; GMM = generalised method of moments; IV = instrumental variables approach; PIMI = Public Investment Management Index. The table shows responses of real GDP (cumulative change in year t relative to year $t=-1$, in percent) to a public investment shock equivalent to 1% of GDP; $t=0$ is the year of the shock. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Impulse response function and estimation details are reported in the Supporting Information.
Source: Authors' estimates.

relatively simple to deal with correlation in error terms—a likely complication in cross-country analysis.[5] The following baseline specification is estimated:

$$log(y_{i,t+k}) - log(y_{i,t-1}) = \alpha_i + \tau_t + \beta_k shock_{i,t} + \boldsymbol{\theta X}_{i,t} + \varepsilon_{i,t} \quad (3)$$

in which $k=0,\ldots,5$ is the forecast horizon in years; $log(y_{i,t+k}) - log(y_{i,t-1})$ represents the cumulative change in real GDP (in percent) over the forecast horizon k;α_i,τ_t are country and time fixed effects to account for time-invariant country heterogeneity and global factors (such as the world business cycle or oil price movements); $\boldsymbol{X}_{i,t}$ is a set of control variables including—as in Abiad et al. [28] and Furceri and Li [38]—two lags of the shocks and two lags of real GDP growth.[6] To control for outliers, data points above the 99th percentile and below the 1st percentile are dropped in the estimations.

The coefficient β_k denotes the response of output in each period k to a public investment shock at $t=0$ ($shock_{i,t}$, identified using the methodology described in the previous section). Specifically, it measures the average cumulative real GDP change in period $t+k$ relative to period $t-1$ (in percent), in response to the public investment shock for the effective sample—the sample of countries used in the estimation. We use two main approaches to estimating the public investment multiplier. First, we use the identified public investment shocks directly in the specification. In this case, the estimated coefficient conveys the average output effect of a public investment shock for the effective sample. To ease interpretation, the estimated coefficients are scaled by the average change in public investment as a percentage of GDP for the effective sample that experienced the public investment shock, so that the impulse responses can be interpreted as the change in output (in percent) in response to a 1% of GDP increase in public investment.[7] Second, we use the identified public investment shocks as an instrument for changes in public investment (as a share of GDP) in the IV-2SLS framework. This approach also mitigates the potential issue with the binary shock variable not conveying the magnitudes of the associated changes in public investment. That said, the instrumental variable approach yields estimates that are very similar to the baseline model results for both unconditional and state-dependent multipliers (see Table 1, the robustness section, and the Supporting Information).

Following the estimation of local projection models, impulse response functions are obtained by plotting the estimated multipliers for $k=0,\ldots,5$, with 90% confidence bands computed using robust standard errors clustered at the country level.

To examine heterogeneity across country groups (low-income countries vs. higher-income countries; commodity-exporting vs. commodity-importing EMDEs) and discrete macroeconomic states (negative and positive output growth periods), the model is estimated separately for each subsample. State-dependent multipliers, conditional on the values of continuous time-varying

variables, are estimated using a local projections framework with a smooth transition function:[8]

$$log(y_{i,t+k}) - log(y_{i,t-1}) = \alpha_i + \tau_t + \beta_k^L F(z_{i,t}) shock_{i,t} + \beta_k^H (1 - F(z_{i,t})) shock_{i,t} + \boldsymbol{\theta} \boldsymbol{X}_{i,t} + \varepsilon_{i,t} \quad (4)$$

with $F(z_{i,t}) = \frac{\exp(-\gamma z_{i,t})}{1+\exp(-\gamma z_{i,t})}$, $\gamma > 0$, in which $z_{i,t}$ is the value of a conditioning variable, normalised to have zero mean and unit variance.[9] The coefficients β_k^L and β_k^H capture the output impact of public investment shocks at each horizon k for the state characterised by low values of a conditioning variable, $F(z_{i,t}) \approx 1$ when z goes to minus infinity; and the state characterised by high values of a conditioning variable, $1 - F(z_{i,t}) \approx 1$ when z goes to plus infinity.

This approach is equivalent to the smooth transition autoregressive model developed by Granger and Teräsvirta [77]. The advantage of this methodology is twofold. First, it permits a direct test of whether the effect of government spending varies across high and low levels of a given conditioning variable. Second, it allows the effect of government spending shocks to change smoothly between the levels of a conditioning variable by considering a continuum of states to estimate the impulse response functions, thus making the responses more stable and precise. To compute multipliers conditional on the public capital scarcity and fiscal space, Equation (4) is estimated using the following conditioning variables for $F(z_{it})$: (i) Gross government debt as a share of GDP as a proxy for fiscal space; and (ii) Public capital stock as a share of GDP to examine the implications of capital scarcity. Variable definitions are provided in Table A2.

4 | Empirical Results

4.1 | Baseline Unconditional Public Investment Multipliers

While public investment constitutes a relatively small share of total investment, it tends to play an important role in promoting economic growth. The estimations using the new methodological framework outlined in Section 3 suggest that, in EMDEs on average, public investment shocks lead to positive output responses that remain highly statistically significant at the horizon of 5 years (Figure 2A).[10] An increase in public investment equivalent to 1% of GDP is associated with a gradual increase in output of 0.4% after 1 year, reaching 1.1% after 5 years. The output effects of public investment tend to be smaller in the short run but increase over the long term as supply-side effects on productivity and productive capacity fully manifest themselves, consistent with the literature [41, 78]. This aligns with Jordà and Taylor [79], who emphasise that fiscal multipliers tend to be larger over medium-term horizons, particularly in the context of public investment, which influences long-run potential output through capital accumulation. In the short run, offsetting fiscal effects, impact of leakage through imports, possible transitory crowding out of private investment, private sector capacity constraints, and the time needed to adjust consumption and production may dampen the effects of public investment.[11] However, Raga [80] finds that fiscal multipliers in developing economies can be substantial when public investment is well-targeted and complements private sector activity, supporting the notion that efficiency and fiscal space are key determinants of multiplier size. The estimated effects are broadly in line with public investment multipliers reported in past empirical work (see Section 2 and Appendix B for a review of the estimates reported in the literature).

Our analysis reveals that the effects are heterogeneous across EMDEs (Figure A2). In higher-income EMDEs, public investment shocks lead to strong and persistent impacts on output. In low-income countries, the effects on output are characterised by a wide dispersion, translating to much lower statistical significance of public investment multipliers, which is partly related to the relatively small sample size for low-income countries. That said, the magnitude of the average effect tends to be larger in low-income countries than in higher-income EMDEs, reaching up to 1.7% over the horizon of 5 years after a public investment shock equivalent to 1% of GDP. Public investment effects also tend to be slightly lower in commodity-exporting EMDEs than in other EMDEs; however, the differences are small and not statistically significant.[12] An alternative estimation approach that uses an interaction term for the shock variable and country groups, rather than estimations of public investment multipliers separately for each sub-sample, confirms these results (see the robustness section and the Supporting Information). In the next section we explore the macroeconomic characteristics that may help to uncover the origins of such heterogeneous effects.

The analysis suggests that potential output also increases steadily in response to public investment. In a sample of EMDEs with the available data, a 1% of GDP rise in public investment leads to an increase in potential output peaking at about 1.1% over 5 years (Figure 2.B).[13] This effect is associated with a concurrent boost in productivity — by up to 0.8% for total factor productivity and 1.9% for labor productivity over the medium term (Figure 2C,D). The productivity effects increase steadily over time and fully manifest themselves in the medium run — after 4 years. The impact of public investment surges on output is not associated with additional inflationary pressures (Figure 2E). These findings support the hypothesis that public investment can increase output through both short-term aggregate demand and longer-run aggregate supply channels, thereby boosting potential output [78]. These results thus are also in line with the Keynesian perspective that public investment not only boosts short-run demand but also raises productive capacity of an economy, and a complementary Kaldor-Verdoorn mechanism as faster output growth supported by public investment induces productivity growth, thereby fostering potential output.

An important impact of public investment occurs via the crowding-in effect on private investment. An increase in public investment equivalent to 1% of GDP induces an increase in private investment by up to 2.2% at the horizon of 5 years (Figure 2F). The estimates also suggest a possible crowding-out effect on impact; however, the effect is small, not statistically significant from zero, and is reversed within a year. The crowding-in effect on private investment is in line with the estimates results in the literature (see, for instance, [29, 38]). In this regard, our findings provide empirical support for policies to mitigate the private investment slowdown through scaling up of public investment. This

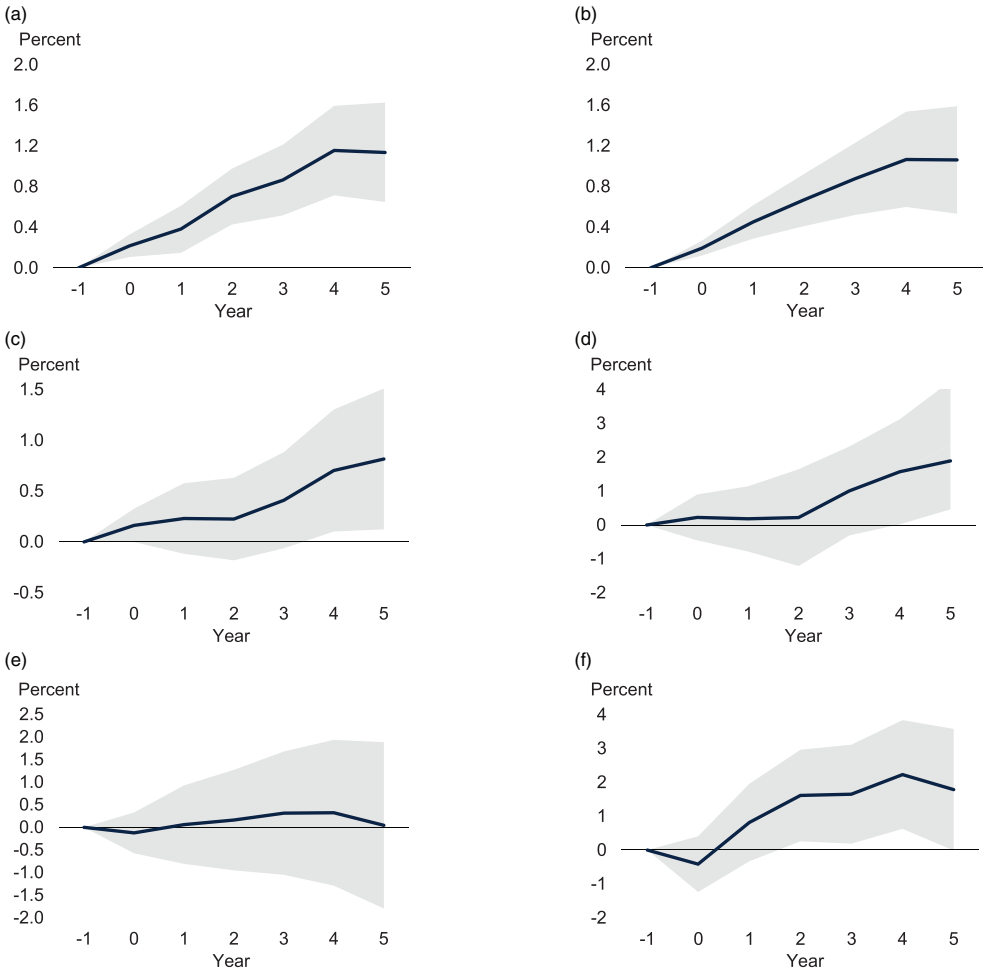

FIGURE 2 | Macroeconomic impacts of public investment in EMDEs. (A) Impact on output. (B) Impact on potential output. (C) Impact on total factor productivity. (D) Impact on labour productivity. (E) Impact on inflation. (F) Impact on private investment. *Source:* Authors' estimates. Responses of variables (cumulative change in year t relative to year $t = -1$, in percent) to a public investment shock equivalent to 1% of GDP; $t = 0$ is the year of the shock. Shaded areas denote 90% confidence bands, based on standard errors clustered at the country level. Responses to a public investment shock of real GDP, real potential GDP, total factor productivity, labor productivity, consumer price index, and real private investment. [Colour figure can be viewed at wileyonlinelibrary.com]

effect could operate through several transmission channels. An increase in public capital can raise the return on private capital by facilitating connectivity (for instance, roads and bridges), thereby facilitating private sector investment [13, 29]. Public investment reduces uncertainty and risks associated with private investment in large infrastructure projects and may also directly crowd in private investment via public-private partnerships [69]. These findings thus provide empirical support for the accelerator mechanism of the crowd-in effect—public investment can boost the marginal productivity of private capital and generate network externalities, thereby raising the level of desired private capital.

4.2 | State-Dependent Public Investment Multipliers

4.2.1 | The Role of the Business Cycle

Public investment multipliers, on average, are greater in magnitude during recessions than during expansions. A 1% of GDP increase in public investment yields an increase in output by 1.1% in times of expansion after 5 years. An equivalent public investment shock in recessions leads to an increase in output of up to 1.6% over the same period. However, the estimates during recessions are characterised by notable heterogeneity across countries, resulting in wider confidence bands (Figure 3). These results are consistent with the empirical literature reporting larger government spending multipliers in recessions.[14]

The position of an economy in the business cycle may affect the size of the multiplier for several reasons. In expansions, public spending stimulus may be less effective because, if the economy is operating close to full capacity, an additional increase in public spending is less likely to crowd in private sector resources.[15] In contrast, economic slack during recessions enables public investment to mobilise unused private sector capacity [83]. Public spending during recessions may also help mitigate unemployment and improve market confidence and is less likely to be accompanied by increasing inflation and interest rates [45, 47].

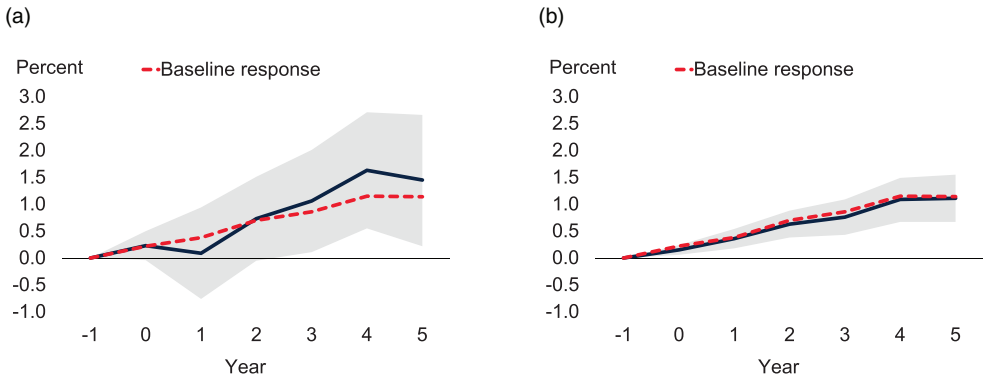

FIGURE 3 | Effects of public investment on output conditional on the business cycle. (A) Impact on output in recessions. (B) Impact on output in expansions. *Source:* Authors' estimates. Responses of real GDP (cumulative change in year t relative to year $t = -1$, in percent) to a public investment shock equivalent to 1% of GDP in recessions and expansions, defined as periods of negative and positive real GDP growth, respectively. Dashed lines indicate the baseline unconditional responses. Shaded area denotes 90% confidence bands, based on standard errors clustered at the country level. [Colour figure can be viewed at wileyonlinelibrary.com]

In practice, however, EMDEs often have limited fiscal resources for public investment projects during recessions and crises. In fact, public investment tends to contract during economic distress. "Shovel-ready" investment projects may help revive economic activity and crowd in private investment during economic downturns as long as they are well-planned and executed, and do not undermine fiscal sustainability; such projects and conditions, however, may not always be present.

4.2.2 | Implications of Fiscal Space

EMDEs with lower fiscal sustainability concerns, as measured by public-debt-to-GDP ratios, experience much stronger positive impacts of public investment: output increases by up to 1.6% 5 years after a public investment shock equivalent to 1% of GDP. Conversely, public investment in countries with high and rising debt (implying limited fiscal space) appears to be ineffective: the estimated public investment multipliers are lower and not statistically significant (Figure 4).[16] While changes in public-debt-to-GDP ratios only partly reflect fiscal space dynamics, these results nevertheless imply that the effect of public investment on output in countries with large fiscal space is up to one percentage point higher than in countries with small fiscal space, on average.[17]

Fiscal space influences the output effects of public investment through two channels. The first is associated with the effects on the private sector, as additional public spending in countries with weak fiscal positions may lead to lower disposable income of liquidity-constrained households, as well as increased tax burdens for the private sector in the future (which may also be anticipated). The second channel relates to the interest rate effect, as the scaling up of government expenditures in countries with high levels of debt may lead to higher international interest rate spreads, on account of higher sovereign risk and inflation, thus increasing borrowing costs for the private sector [30, 84–85]. Infrastructure investment projects, given their large upfront costs and long time horizons, are often financed by borrowing rather than from current government revenues. Larger fiscal space implies that the sovereign has more capacity to service its borrowing and therefore is more creditworthy, allowing it to finance such investment at a lower interest rate.

4.2.3 | Implications of Public Investment Efficiency

The efficiency of public investment plays a crucial role in driving its growth effects.[18] The estimates suggest a greater effect on GDP in response to public investment shocks in EMDEs with the highest efficiency, culminating in an increase in output of about 1.6% after 5 years—one-half percentage point higher than the effect of public investment in EMDEs with the lowest efficiency (Figure 5). In countries with the lowest efficiency, the effects of public investment are lower and not statistically significant (albeit still positive).

These results are consistent with empirical studies using other samples and methods and provide support for the argument that low public investment efficiency is problematic.[19] Poor design, evaluation, and implementation of investment projects, including issues with corruption and governance, can deplete valuable fiscal resources without necessarily increasing the quantity or quality of public infrastructure that supports growth [6, 7, 32]. Therefore, well-designed public investment management processes are essential to ensure the effectiveness of public investment.

4.2.4 | Initial Public Capital Stock

The impact of public investment on output also varies with the initial level of the public capital stock (Figure 6). The magnitude and statistical significance of the public investment multiplier tend to decrease with the level of public capital stock relative to GDP, consistent with expectations of diminishing marginal returns to capital. Specifically, a 1% of GDP increase in public investment is associated with a 1.7% increase in GDP after 5 years in capital-scarce countries. This contrasts with 0.9% (not statistically significant in the medium term) when the public-capital-stock-to-GDP ratio is high. Similar results are

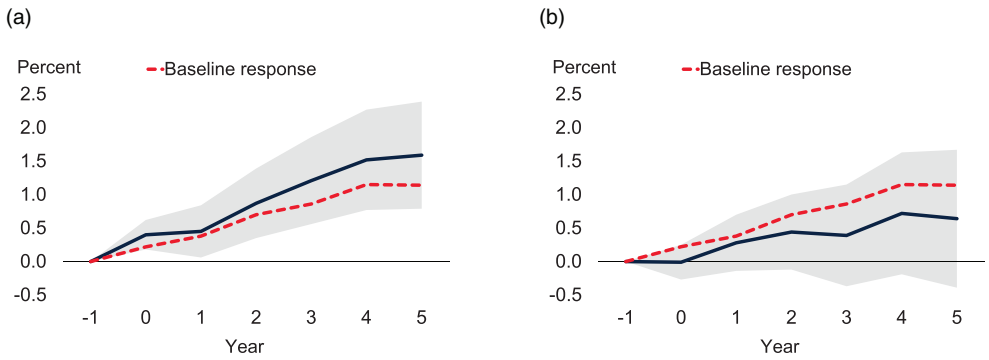

FIGURE 4 | Effects of public investment on output conditional on fiscal space. (A) Large fiscal space. (B) Small fiscal space. *Source:* Authors' estimates. Responses of real GDP (cumulative change in year t relative to year $t=-1$, in percent) to a public investment shock equivalent to 1% of GDP, conditional on fiscal space. $t=0$ is the year of the shock. Dashed line indicates the baseline unconditional response. Shaded area denotes 90% confidence bands, based on standard errors clustered at the country level. The distinction between large and small fiscal space is based on the Local Projections Smooth Transition Autoregressive (LP-STAR) function, using central government debt (% GDP) as the transition variable. [Colour figure can be viewed at wileyonlinelibrary.com]

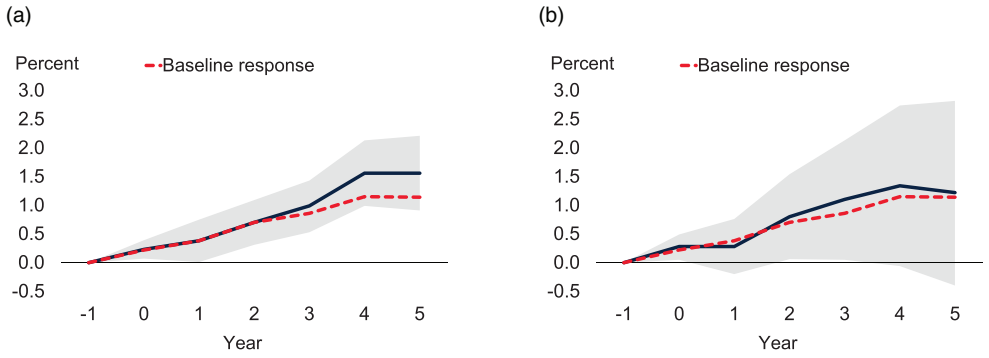

FIGURE 5 | Effects of public investment on output conditional on public investment efficiency. (A) High investment efficiency. (B) Low investment efficiency. *Source:* Authors' estimates. Responses of real GDP (cumulative change in year t relative to year $t=-1$, in percent) to a public investment shock equivalent to 1% of GDP, conditional on fiscal space. $t=0$ is the year of the shock. Dashed line indicates the baseline unconditional response. Shaded area denotes 90% confidence bands, based on standard errors clustered at the country level. High-efficiency and low-efficiency samples are based on the top and bottom quartiles of the IMF [69] public infrastructure efficiency index, which ranges from 0 to 100 (the values above 81 and below 47, respectively). [Colour figure can be viewed at wileyonlinelibrary.com]

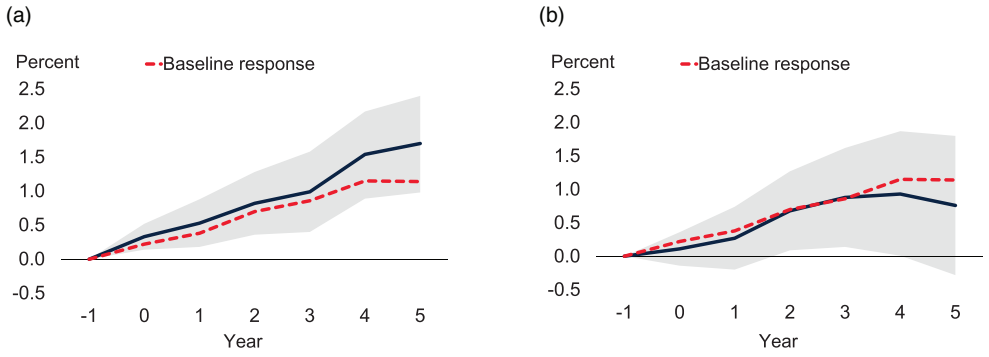

FIGURE 6 | Effects of public investment on output conditional on public capital stock. (A) Small public capital stock. (B) Large public capital stock. *Source:* Authors' estimates. Responses of real GDP (cumulative change in year t relative to year $t=-1$, in percent) to a public investment shock equivalent to 1% of GDP, conditional on fiscal space. $t=0$ is the year of the shock. Dashed line indicates the baseline unconditional response. Shaded area denotes 90% confidence bands, based on standard errors clustered at the country level. Small public capital stock and large public capital stock responses are based on local projections with the smooth transition function that uses public-capital-stock-to-GDP ratio as the conditioning variable to capture historically lowest and highest capital stock ratios of a given country in public investment shock years (the values of public capital stock of 68 and 113% of GDP for a median EMDE, respectively). [Colour figure can be viewed at wileyonlinelibrary.com]

found in empirical studies using other samples and methods (for instance, [40]).

4.2.5 | Robustness, Sensitivity Checks, and Additional Empirical Exercises

We assess the credibility of our public investment shock identification and the stability of the estimated macroeconomic effects using a broad battery of checks. Table 1 summarises selected estimates at $t = 1$ and $t = 5$: multipliers from IV (2SLS) are virtually identical to the baseline (0.4 and 1.0 vs. 0.4 and 1.1), GMM yields slightly smaller long-horizon effects (0.8 at $t = 5$), dropping country fixed effects raises the long-horizon multiplier (to 1.5), and results are stable when excluding the lagged dependent variable, restricting to the pre-2007 period, or adding inflation and trade controls. Table 1 also confirms state-dependent multiplier estimates using alternative approaches: multipliers are weaker when debt is rising and stronger when debt is falling, and they are systematically larger when public investment efficiency is higher as measured by alternative indexes ([6] PIMI; Devadas–Pennings 2018; CPIA indexes). For brevity, below we provide a brief description of selected robustness checks, while implementation details, complete outputs, and additional exercises are provided in the Supporting Information and are also available from the authors on request.

Exogeneity and fiscal foresight. Panel Granger non-causality tests, regressions of shock incidence on lagged macro controls (GDP growth, inflation, debt), and foresight diagnostics using real-time growth forecasts indicate shocks are orthogonal to recent and expected macroeconomic conditions. Reverse local-projection "pre-trend" tests—regressing shock incidence on future growth with standard controls—likewise show no anticipatory dynamics. Introducing leads of shocks to the local projections model also does not alter the estimates (see Supporting Information: Section A for details).

Sample selection and weighting. A doubly-robust augmented inverse probability weighted (AIPW) estimator, combining outcome modelling with propensity-score weights for shock incidence, delivers impulse responses that are largely identical to the baseline.

Continuous shock definitions and alternative identification. Replacing the binary shock indicator with continuous measures based on cyclically adjusted public investment—either the growth rate or the change in CAPI as a share of GDP—produces similar output responses and confirms larger effects for larger investment impulses. In addition, the IV-2SLS method reported above uses instrumented public investment (as a share of GDP), rather than the public investment shock variable directly, to estimate unconditional and state-dependent multipliers. As discussed in Section 3.2 and detailed in the Supporting Information, the resulting multipliers and dynamics are nearly identical to the baseline, reinforcing the robustness of the identification.

Sensitivity to the choice of thresholds and statistical filters. Tightening the shock definition to a two-standard-deviation cutoff and recomputing the cyclical component of public investment with Baxter–King, Christiano–Fitzgerald, and Hamilton filters leaves the results essentially unchanged.

Alternative model specification and estimator choices. Results are robust to including or excluding country fixed effects, augmenting the conditioning variable set (inflation, trade openness, real interest rate), dropping the lagged dependent variable, and using GMM estimators. Alternative measures of fiscal space and public investment efficiency also yield estimates similar to the baseline state-dependent multipliers (see Table 1 and Supporting Information).

Sample sensitivity. Restricting the sample to the pre-2007 period and using a common-country sample across specifications does not alter conclusions, though precision naturally declines with fewer observations. The results are virtually unchanged when the country composition is altered; for instance, China or BRICS countries are excluded.

Implications of monetary policy frameworks and impact on interest rates. The effect of public investment shocks on real interest rates is positive, but not statistically significant. Fixed exchange rate and managed float regimes are associated with greater and more statistically significant public investment multipliers than in countries with a free float exchange rate regime, which confirms findings in the previous literature [27, 38–39].

Asymmetric effects of public investment shocks. To examine whether positive and negative investment shocks have asymmetric effects, we estimate separate local projections for expansionary and contractionary shocks. Positive shocks are defined as changes in cyclically adjusted public investment that exceed the country-specific mean by more than one standard deviation (as in the baseline specification), while negative shocks fall below the mean by more than one standard deviation. The results show that expansionary shocks generate significantly larger and more persistent increases in output, whereas contractionary shocks are associated with much smaller and statistically weaker effects, becoming insignificant after about 4 years. Rather than reflecting any rigidity on the spending side, the muted responses to negative shocks are consistent with some degree of private-sector adjustment—through investment or consumption—that partially offsets declines in public investment, and with the fact that negative shocks tend to occur in higher-debt environments where fiscal multipliers are smaller. Corresponding impulse responses are shown in the Supporting Information.

5 | Conclusion and Policy Implications

In this article, we contribute to the literature by introducing a new methodology to identify public investment shocks that can be easily replicated and extended by other researchers going forward. We use the identified public investment shocks to examine the macroeconomic implications of public investment for EMDEs using a broader sample than employed in the earlier literature, which allows a more granular analysis of cross-country heterogeneity and non-linear effects associated with prevailing macroeconomic conditions and country structural characteristics.

The estimation results confirm the findings of previous research and expand the empirical evidence to a broad sample of EMDEs. Inter alia, our paper provides new insights into the heterogeneity of public investment multipliers across country groups and helps to cast light on the factors that explain the varying growth effects of public investment. In this regard, a particularly noteworthy aspect of our results is that the positive effects of public investment on economic growth can be significantly bolstered under certain conditions that are feasible to achieve with robust policy interventions. In particular, fiscal space and public spending efficiency are crucial for bolstering the positive effects of public investment. While the scaling up of public investment by 1% of GDP on average raises output by 1.1% after 5 years, in countries with ample fiscal space and high public investment efficiency the effects are much higher—reaching 1.6% over the same period. These results help inform policy debates on the macroeconomic effects of public spending, particularly in the context of developing economies, which generally have larger infrastructure gaps and unmet funding needs to address sustainable development goals.

The positive effects of public investment reflect both the beneficial aggregate demand and supply impacts, including through boosting the productive capacity of the economy and the crowding in of private investment. The latter is particularly important for EMDEs given the prolonged weakness in private investment growth they experienced over the past decade and the massive private capital mobilisation needs to address investment gaps.

Furthermore, the results suggest that in countries with low fiscal space, public investment multipliers tend to be lower and statistically insignificant. Thus, limited fiscal space not only impedes the ability of a government to scale up public investment but also undermines its effectiveness. This underscores the importance of boosting fiscal space during good times to help provide room for manoeuvre during recessions. If public debt ratios do not decrease during times of economic expansion, countries may be unable to avail themselves of countercyclical spending increases to help dig themselves out of recessions. As the paper also shows, scaling up of public investment is especially effective during recessions. Redoubled policy efforts to boost fiscal space—such as reforms to improve tax collection efficiency, enhance fiscal frameworks, and curtail unproductive expenditures—are particularly important in light of the significantly elevated debt levels over the past decade.

Finally, our results accentuate the large payoffs that countries could realise by strengthening public investment efficiency. Policy interventions that can improve the efficiency of public investment range from broad structural reforms to improve the quality of institutions—tackling corruption, poor governance, and limited capacity of fiscal administration—to policies that focus more narrowly on enhancing public investment project management frameworks. This includes reforms to strengthen the planning, allocation, implementation, and monitoring of public investment projects. Low-income countries that face particularly deep structural challenges, vast infrastructure gaps, and limited fiscal resources have much lower capacity to undertake such reforms on their own. Therefore, extensive coordinated support from the global community, including both financial support and technical assistance, is imperative to help these countries address their pressing development needs.

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Endnotes

[1] From a theoretical perspective, the crowding-in effects are related to the accelerator mechanism, as scaling up public investment, if well-implemented, can raise the marginal productivity of private capital and generate network externalities, thereby raising the level of desired private capital. see also Erenburg and Wohar [31] and IMF [32] for related discussions.

[2] Countries with less than 20 continuous observations were not included in the sample going forward.

[3] The raw-extreme threshold is computed over the pooled cross-country distribution of annual changes. Results are similar if we (i) use a positive-tail definition (95th percentile of Δ(public investment/GDP)) or (ii) scale IRFs with the mean Δ(*PI/GDP*) among observations flagged by each shock.

[4] Because the public investment shock indicator captures relatively rare, discrete events, country-level AR(1) tests are uninformative: in many countries the lag often takes a constant value or is omitted. For this reason, we rely on correlation-based orthogonality checks, as suggested by an anonymous referee.

[5] See also Plagborg-Møller and Wolf [76] for a discussion on the trade-offs between VARs and local projections.

[6] Among other robustness checks, the model is also estimated with additional control variables to examine the omitted variable bias, dropping lagged real GDP growth, and using the generalised method of moments (GMM) estimator to address possible bias arising from the lagged dependent variable.

[7] This ex-post rescaling to a 1% of GDP shock is standard in the empirical multiplier literature (see, e.g., [37, 39]). Ramey and Zubairy [63] propose a one-step IV approach that directly estimates cumulative multipliers. While our methodology differs, the rescaling procedure yields consistent interpretations of impulse responses and is widely used in cross-country applications.

[8] The same approach was used to estimate state-dependent public spending multipliers in Abiad et al. [28], Furceri and Li [38], Miyamoto et al. [43], and Honda et al. [27].

[9] The weights assigned to each regime vary between 0 and 1 according to the weighting function so that $F(z_{i,t})$ can be interpreted as the probability of being in a given economic state. Following the literature that uses a similar approach (Abiad et al. [28] and [38]), the parameter is set to 1.5, while the results do not change materially when other values are used.

[10]Results are virtually identical when excluding China or the BRICS: medium-term responses overlap the baseline within the 90% confidence region across all horizons (see the discussion in the robustness section of the paper and sample sensitivity checks in Supporting Information: Section E).

[11]Similar results are reported in recent empirical studies (for instance, [28, 38–39]).

[12]Lower public investment multipliers in commodity-exporting EMDEs are consistent with the significantly lower public investment efficiency in these countries [2, 6]. As we show in Section 4.2, public investment multipliers are lower in countries with low government spending efficiency.

[13]The sample size for the exercises with potential output and productivity is smaller because of data availability, and therefore the estimates may not be directly comparable to the baseline results, which use the full EMDE sample.

[14]Larger public investment multipliers in recessions are reported in Auerbach and Gorodnichenko [45]; Caggiano et al. [81]; Furceri and Li [38]; Honda et al. [27]; Riera-Crichton et al. [46]. That said, such estimates may not be fully robust with significant heterogeneity across countries [82].

[15]That said, during expansions public investment also has a positive effect on output in EMDEs. This is in line with the view that EMDEs often have underutilised capacity because of infrastructure gaps, limited access to finance constraining the ability of the private sector to expand production capacity, and unused available labour resources, which can be engaged in expansions through public investment.

[16]These results thus are in line with the literature, arguing that in countries with high debt, public spending multipliers can be insignificant or even negative [30, 39].

[17]The high-debt and low-debt states are defined using the smooth transition function that reflects the historical dynamics of public-debt-to-GDP ratios on a country-by-country basis. For a median EMDE, a low-debt state over the sample period corresponds to about 30% of GDP and a high-debt state corresponds to about 80% of GDP for EMDEs that experienced a public investment shock. The results are also confirmed using an alternative approach that examines the size of public investment multipliers in countries experiencing large increases or decreases in their debt-to-GDP ratios—see the results in the robustness section and Table 1.

[18]The analysis uses the IMF [69] public infrastructure efficiency index, which is a cross-sectional index available for 120 countries (including 93 EMDEs), produced using the data envelopment analysis. The index ranges from 0 to 100, with higher values indicating better efficiency. The model was also estimated using the Devadas and Pennings [70] infrastructure efficiency index and the Dabla-Norris et al. [6] public investment management index. Estimations using alternative measures also suggest statistically insignificant and lower output effects of public investment in low-efficiency economies (see the additional results in the robustness section and Table 1).

[19]See, for instance, Cavallo and Daude [9]; Furceri and Li [38]; IMF (2014); Izquierdo et al. [40]; Leduc and Wilson [41]; Leeper et al. [51].

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** obes70058-sup-0001-Supinfo.doc.

Appendix A

TABLE A1 | Sample composition and subgroups.

Emerging market and developing economies (EMDEs)	Albania, Algeria, Angola, Antigua and Barbuda, Argentina, Armenia, Azerbaijan, The Bahamas, Bahrain, Bangladesh, Barbados, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Central African Republic, Chad, Chile, China, Colombia, the Comoros, the Democratic Republic of Congo, the Republic of Congo, Costa Rica, Côte d'Ivoire, Djibouti, Dominica, the Dominican Republic, Ecuador, the Arab Republic of Egypt, El Salvador, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Fiji, Gabon, The Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, India, Indonesia, the Islamic Republic of Iran, Iraq, Jordan, Kazakhstan, Kenya, Kuwait, Lao PDR, Lebanon, Lesotho, Liberia, Libya, Madagascar, Malawi, Malaysia, Maldives, Mali, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, North Macedonia, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, the Philippines, Poland, Romania, the Russian Federation, Rwanda, São Tomé and Príncipe, Saudi Arabia, Senegal, Serbia, the Seychelles, Sierra Leone, South Africa, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sudan, the Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Uganda, Ukraine, the United Arab Emirates, Uruguay, Uzbekistan, Viet Nam, the Republic of Yemen, Zambia.
Low-income countries (LICs)	Burkina Faso, Burundi, Central African Republic, Chad, the Republic of Congo, Eritrea, Ethiopia, The Gambia, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Sudan, the Syrian Arab Republic, Togo, Uganda, the Republic of Yemen.
Commodity-exporting EMDEs	Algeria, Angola, Argentina, Armenia, Azerbaijan, Bahrain, Belize, Benin, Bolivia, Botswana, Brazil, Brunei Darussalam, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Chile, Colombia, the Comoros, the Democratic Republic of Congo, the Republic of Congo, Costa Rica, Côte d'Ivoire, Ecuador, Equatorial Guinea, Eritrea, Ethiopia, Fiji, Gabon, The Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Indonesia, the Islamic Republic of Iran, Iraq, Kazakhstan, Kenya, Kuwait, Lao PDR, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mongolia, Mozambique, Myanmar, Namibia, Nicaragua, Niger, Nigeria, Oman, Papua New Guinea, Paraguay, Peru, the Russian Federation, Rwanda, Saudi Arabia, Senegal, the Seychelles, Sierra Leone, South Africa, Sudan, São Tomé and Príncipe, Tajikistan, Tanzania, Togo, Uganda, Ukraine, the United Arab Emirates, Uruguay, Uzbekistan, the Republic of Yemen, Zambia.
Commodity-importing EMDEs	Albania, Antigua and Barbuda, The Bahamas, Bangladesh, Barbados, Bhutan, Bosnia and Herzegovina, Bulgaria, Cambodia, China, Croatia, Djibouti, Dominica, the Dominican Republic, the Arab Republic of Egypt, El Salvador, Eswatini, Georgia, Grenada, Haiti, Hungary, India, Jordan, Lebanon, Lesotho, FYR Macedonia, Malaysia, Maldives, Mauritius, Mexico, Moldova, Montenegro, Morocco, Nepal, Pakistan, Panama, the Philippines, Poland, Romania, Serbia, Sri Lanka, St. Kitts and Nevis, St. Lucia, St., the Syrian Arab Republic, Thailand, Tunisia, Viet Nam.

Note: The sample composition follows the World Bank's classification of EMDEs and country groups.

TABLE A2 | Data definitions and sources.

Variable	Definition	Source
Real public investment	General government investment (gross fixed capital formation) in billions of national currency deflated using the GDP deflator	Investment and Capital Stock Dataset [67]
Real private investment	Private investment (gross fixed capital formation), in billions of national currency deflated using the GDP deflator	Investment and Capital Stock Dataset [67]
Real GDP	Gross domestic product, in billions of national currency deflated using the GDP deflator	IMF World Economic Outlook Database
Potential GDP	Index derived from real potential output growth estimated using the production function approach	Potential growth database [71]
Inflation	Growth rate of consumer price index, in percent	IMF World Economic Outlook Database
Labor productivity	Real GDP per average annual hours worked by persons engaged	Penn World Table 10.01
Total factor productivity	Total factor productivity in constant national prices (2017 = 1)	Penn World Table 10.01
Public debt	General government debt, percent of GDP	World Bank's Fiscal Space Database [68]
Public infrastructure efficiency index [69]	Public infrastructure efficiency index constructed based on the data envelopment analysis using the volume and quality of infrastructure as output, and public capital stock and per capita GDP as input variables	IMF [69]
Public infrastructure efficiency index [70]	Infrastructure efficiency index constructed as a weighted average of the quality of electricity, water, and road infrastructure	Devadas and Pennings [70]
Public investment management index (PIMI)	Index based on country performance scores in public investment project appraisal, selection, implementation, and evaluation	Dabla-Norris et al. [6]
Public capital stock	General government capital stock, percent of GDP	Investment and Capital Stock Dataset [67]
Real interest rate	Lending interest rate adjusted for inflation as measured by the GDP deflator	World Bank's World Development Indicators, IMF's International Financial Statistics

Source: Authors.

TABLE A3 | Summary statistics for public investment shocks.

Variable	Value
Number of economies	129
Public investment shock = 1	
Number of observations	557
Mean real GDP growth (percent)	4.48
Mean public investment (percent of GDP)	8.11
Mean change in public-investment-to-GDP ratio (percentage points)	2.68
Public investment shock = 0	
Number of observations	3804
Mean real GDP growth (percent)	3.79
Mean public investment (percent of GDP)	6.76
Mean change in public-investment-to-GDP ratio (percentage points)	−0.43

Note: The table reports descriptive statistics for output growth and public investment, distinguishing between episodes of public investment shock *(public investment shock = 1)* and non-shock periods *(public investment shock = 0)*.
Source: Authors.

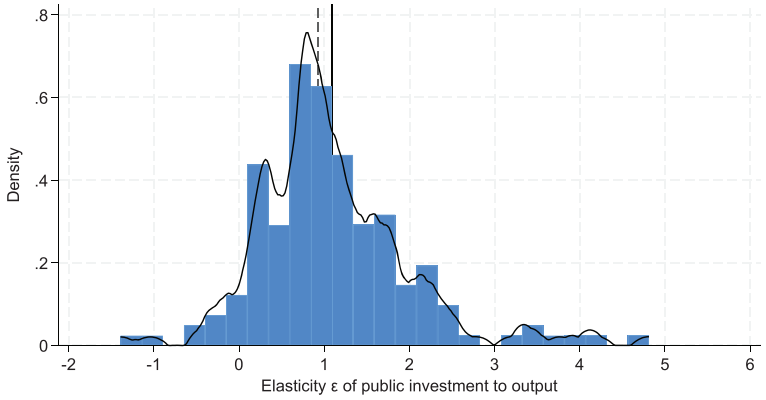

FIGURE A1 | Distribution of the output elasticity of public investment (ε). *Source:* Authors. Histogram with kernel density of the estimated elasticity ε from country-specific log–log regressions of ln(public investment) on ln(GDP) over available years. The dashed vertical line marks unit elasticity ($\varepsilon = 1$). Summary statistics: Mean = 1.088, median = 0.926, $N = 10{,}544$ country-year observations. [Colour figure can be viewed at wileyonlinelibrary.com]

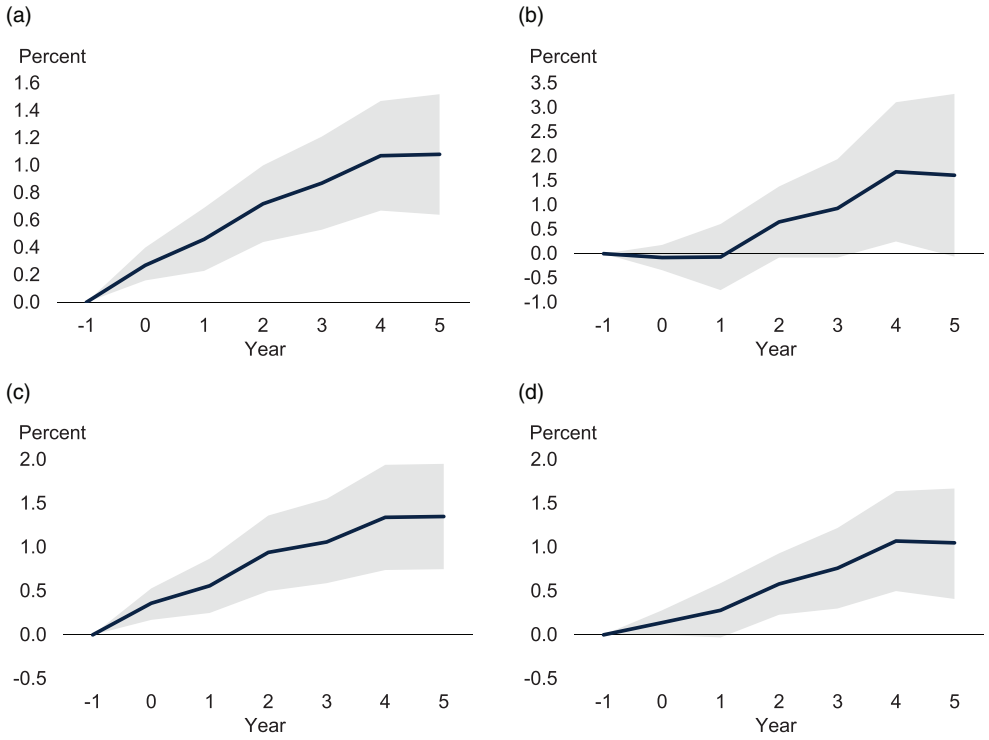

FIGURE A2 | Impact of public investment on real GDP by EMDE country groups. (A) EMDEs excluding low-income countries. (B) Low-income countries. (C) Commodity-importing EMDEs. (D) Commodity-exporting EMDEs. *Source:* Authors. EMDEs = emerging market and developing economies; LICs = low-income countries. Responses of real GDP (cumulative change in year t relative to year $t = -1$, in percent) to a public investment shock equivalent to one percent of GDP; t = 0 is the year of the shock. Sample includes 129 EMDEs, of which 23 are LICs, 48 are commodity exporters, and 81 are commodity importers. Shaded areas denote 90% confidence bands, based on standard errors clustered at the country level. Country composition is shown in Table A1. [Colour figure can be viewed at wileyonlinelibrary.com]

Appendix B

TABLE B1 | Output effects of public investment: Summary of the literature.

Study	Public investment multiplier	Sample	Methodology	Notes
Abiad et al. [28]	0.4 (year 0)–1.4 (year 4)	17 OECD economies; 1985–2013	Local projections with forecast error shocks	Output growth in response to a 1% of GDP increase in public investment. Larger multipliers in low-growth episodes and in countries with high spending efficiency.
Auerbach and Gorodnichenko [45]	2.12 (peak response over 20 quarters)	US; 1947–2008	SVAR with forecast error shocks	Cumulative output effect in dollars in response to a 1 dollar increase in public investment. Larger multipliers in recessions that in expansion.
Barry et al. [86]	0.16 (quarter 1)–1.10 (quarter 12)	Cameroon; 1999–2015	SVAR with Blanchard-Perotti identification	Cumulative change in output in percent in response to a 1% increase in public investment. Statistically insignificant for most of the forecast horizon and in the longer run.
Bom and Ligthart [10]	0.08 (short run)–0.12 (long run)	68 studies over 1983–2008	Meta-regression analysis	Meta-regression estimates of output elasticity of public capital based on studies utilising a production-function approach. Impact on output growth in response to a 1% increase in public capital.
David [87]	0.1 (quarter 0)–2.1 (quarter 20)	Paraguay; 1998–2015	SVAR with Blanchard-Perotti identification	Output growth in percent, in response to a 1% increase in public investment. Larger multipliers for public investment than for public consumption.
Deleidi et al. [74]	[0.9–1.2] in year 0; [1.9–3.4] in year 6	11 euro area countries; 1970–2016	Local projections	Output growth in response to a 1% increase in public investment. Smaller multipliers in the pre-2007 period. The ranges of individual country estimates are in parentheses.
Demetriades and Mamuneas [88]	[0.36–2.06] in the short run; [0.36–1.97] in the long run	12 OECD countries; 1972–1991	Simultaneous equations system	Output elasticities. Impact on output of a 1% increase in public capital. The ranges of individual country estimates are in parentheses.
Eden and Kraay [29]	1.5 (year 1)	39 low-income countries (IDA borrowers)	2SLS with Kraay [57] identification	Output increase in dollars in response to a 1 dollar increase in public investment. Lower multiplier using OLS (0.2).
Elkhdari et al. [89]	0.3 (year 1)–1.2 (year 5)	Algeria; 2008–2015	SVAR with Blanchard-Perotti identification; location projections	Output growth in response to a 1% increase in capital expenditures. Larger multipliers during periods with negative output gaps.
	0.5 (year 1)–1.8 (year 5)	9 MENA countries; 2000–2015		
Espinoza and Senhadji [90]	0.2–0.3 in the short term; 0.6–1.1 in the long term	Gulf Cooperation Council countries; 1975–2009	Panel models	Output growth in response to a 15% increase in capital expenditures. Larger multipliers for public investment than for public consumption.
Furceri and Li [38]	0.2 (year 1)–0.4 (year 4)	79 EMDEs; 1990–2013	Local projections with forecast error shocks	Output growth in response to a 10% increase in public investment. Larger multipliers during economic slack, in closed economies, in countries with fixed exchange rates, lower public debt, and higher investment efficiency.
Gbohoui [49]	0.55 (year 0) – 0.07 (year 2)	Advanced economies; 1996–2019	Local projections with forecast error shocks	Output growth in response to a 1% of GDP increase in public investment. Larger multipliers during heightened uncertainty.
	0.22 (year 0) – 0.56 (year 2)	EMDEs; 1990–2019		
Gechert and Rannenberg [11]	0.6	98 empirical studies	Meta-regression analysis	Output growth in response to a 1% of GDP increase in public investment. Larger multipliers during economic downturns.

(Continues)

TABLE B1 | (Continued)

Study	Public investment multiplier	Sample	Methodology	Notes
Gonzales-Garcia et al. [91]	0.12 (year 0); 0.37 (4 quarters); 0.44 (after 4 years)	Eastern Caribbean Currency Union: 1994–2009	SVAR with Blanchard-Perotti identification	Cumulative output growth in response to a 1% of GDP increase in public investment. Larger multipliers for public investment than for public consumption (the latter are not statistically significant).
Honda et al. [27]	0.1 (year 1)–0.2 (year 2)	42 low-income countries; 1995–2017	Local projections with forecast error shocks	Output growth in response to a 1% of GDP increase in public investment. Larger multipliers in recessions, under a fixed exchange rate regime, in countries with better institutions.
Ilzetzki et al. [39]	0.4 (quarter 0)–1.5 (quarter 20)	High income countries; 1985–2013	SVAR with Blanchard-Perotti identification	Cumulative output response to public investment shocks. Larger multipliers in countries with fixed exchange rates, closed economies, countries with low debt (not stat. significant in high-debt sample).
	0.6 (quarter 0)–1.6 (quarter 20)	Developing countries; 1985–2013		
IMF [32]	0.4 (year 0)–1.5 (year 4)	Advanced economies; 1985–2013	Local projections with forecast error shocks	Output response to a 1% of GDP increase in public investment. Larger multipliers during low growth and in countries with higher spending efficiency.
	(a) 0.3 in year 0–0.5 in year 4; (b) 0.5 in year 0–0.9 in year 4	Developing economies; 1990–2013	Local projections with shocks based on Corsetti et al. [92] and Kraay [57]	Output response to a 1% of GDP increase in public investment. Shock identification: (a) Corsetti et al. [92] approach based on fiscal rules; (b) Kraay [57] methodology based on official development assistance.
Izquierdo et al. [40]	0.2–1.4 after 2 years	31 European countries, U.S. states, Argentine provinces	Local projections with Blanchard-Perotti, forecast error, and IV identification	Output growth in response to a 1% increase in public investment. Larger multipliers in countries with low public capital stock; statistically insignificant multipliers in countries with low spending efficiency.
Jong-A-Pin and de Haan [93]	Ranging from about −2.5 to 2.5	21 OECD countries over 1960–2001	VAR	Output elasticity of public capital at the horizon of 20 years. Output growth in response to a 1% increase in public capital.
Minea and Mustea [94]	0.53 (year 1)–1.18 (year 10)	Mediterranean countries; 1980–2012	PVAR	Cumulative output growth in response to a 1% increase in public investment. Heterogeneous multipliers across country groups within the sample: larger in Asian, smaller in African countries.
Miyamoto et al. [43]	0.2 (year 0)–1.2 (year 4)	17 advanced economies	Local projections with forecast error shocks	Output growth in response to a 1% of GDP increase in public investment. Statistically insignificant in low-income countries. Larger multipliers in countries with better governance.
	0.2 (year 0)–0.5 (year 4)	39 EMDEs		
Petrović et al. [95]	0.7–0.8 (after 1 year)	10 Central and Eastern European countries	Local projections and SVAR with Blanchard-Perotti identification	Cumulative output growth in percent in response to a 1% increase in public investment. Larger multipliers in low-growth periods.
Puig [96]	1.03 over 2 years	Argentina; 1993–2012	SVAR	Increase in output in dollars in response to a 1 dollar increase in public investment. Greater impact of public investment than public consumption.
Rafiq and Zeufack [97]	2.7 in recessions; 2.0 in expansions (year 1)	Malaysia; 1981–2004	SVAR with Blanchard-Perotti identification	Output growth in response to a 1% increase in public investment. Greater impact of public investment than public consumption.
Warner [44]	0.14 (year 0)	124 EMDEs; 1960–2011	OLS	Output per capita growth in response to a 1% increase in public investment. Insignificant impact in the long run.

Source: Authors.