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The macroeconomic effects of public investment: Evidence from advanced economies

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ABSTRACT

This paper provides new evidence of the macroeconomic effects of public investment in advanced economies. Using public investment forecast errors to identify the causal effect of government investment as well as model simulations, the paper finds that increased public investment raises output, both in the short term and in the long term, crowds in private investment, and reduces unemployment. Several factors shape the macroeconomic effects of public investment. When there is economic slack and monetary accommodation, demand effects are stronger, and the public-debt-to-GDP ratio may actually decline. Public investment is also more effective in boosting output in countries with higher public investment efficiency and when it is financed by issuing debt.

1. Introduction

As the world emerges from the global financial crisis, the recovery in many advanced economies remains tepid. There are now worries that demand will remain persistently weak—a possibility that has been described as "secular stagnation" (Summers 2013; Teulings and Baldwin 2014). One response that is being considered (see for example the European Commission 2014) is an increase in public infrastructure investment, which could provide a much-needed fillip to demand and is one of the few remaining policy levers available to support growth. But there are open questions about the size of the public investment multipliers and the long-term returns on public capital, both of which play a role in determining how public-debt-to-GDP ratios will evolve in response to higher public investment.

To assess appropriately the benefits and costs of increasing public investment in infrastructure, it is critical to determine what macroeconomic impact public investment will have. To what extent does it raise output, both in the short and the long term? Does it increase the public-debt-to-GDP ratio? How do these effects vary with key characteristics of the economy, such as the degree of economic slack, the efficiency of public investment, and the way the investment is financed?

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To address these questions, we examine the historical evidence on the macroeconomic effects of public investment in 17 Organisation for Economic Co-operation and Development (OECD) economies over the 1985–2013 period. Following the methodology pioneered in the recent work by Auerbach and Gorodnichenko (2013a, b), we identify the causal impact of higher public investment on output, private investment, unemployment, and public debt ratios using forecast errors as a measure of unanticipated shocks to government investment.[1] Using the local projections approach of Jordà (1995), we trace out the short- and medium-run response of macroeconomic aggregates to changes in public investment. We then examine the role of three key factors that can potentially shape these responses: the degree of economic slack, the efficiency of public investment and the way it is financed.[2] The empirical findings are complemented by model simulations using the International Monetary Fund's (IMF) Global Integrated Monetary and Fiscal (GIMF) model, which allow us to study the longer term effects of public investment and isolate more precisely the role of cyclical conditions, and of public investment efficiency.

Our main findings are as follows. Increased public investment raises output, both in the short term because of demand effects and in the long term as a result of supply effects. But these effects are shaped by a number of mediating factors, including (1) the degree of economic slack and monetary accommodation, (2) the efficiency of public investment, and (3) how public investment is financed. When there is economic slack and monetary accommodation, demand effects are stronger, and the public-debt-to-GDP ratio may actually decline. The output effects are also bigger in countries with a high degree of public investment efficiency, where additional public investment spending is not wasted and is allocated to projects with high rates of return. Lastly, an increase in public investment that is debt-financed could have larger output effects than one that is budget-neutral, with both options delivering similar declines in the public-debt-to-GDP ratio.

This paper contributes to several strands of literature. First, it reexamines the role of infrastructure and public investment in economic development. A large body of literature has focused on the optimal scale of public investment by estimating the long-term elasticity of output to public and infrastructure capital using a production function approach (see Romp and de Haan 2007; Straub 2011; and Bom and Ligthart 2014, for surveys of the literature). Empirically, however, it is difficult give a causal interpretation to estimates obtained using this approach. Unobservable factors may affect both economic performance and government investment decisions, and the relationship between the two likely runs in both directions. In contrast, our analysis adopts an empirical strategy that allows estimation of causal effects of public investment on a range of macroeconomic variables, in both the short- and medium-term. The paper also builds on the extensive literature on the macroeconomic effects of fiscal policy and how these might be shaped by the state of the business cycle and other factors (see, among others, Blanchard and Perotti 2002; Favero and Giavazzi 2009; Romer and Romer 2010; Kraay 2012, 2014; Auerbach and Gorodnichenko 2013a, b; Blanchard and Leigh 2013; Owyang et al. 2013; and Ramey and Zubairy 2014). Most of these papers do not distinguish between the effects of government consumption and government investment;[3] nor do they examine the longer term effects of fiscal shocks. Finally, the paper contributes to the recent literature that has used DSGE models to analyze the effects of government spending shocks in a liquidity trap, including papers by Cogan et al. (2010), Freedman et al. (2010), Erceg and Linde (2010a, b), Eggerston (2011), Woodford (2011), Christiano et al. (2011), and Coenen et al. (2012).

The rest of the paper is organized as follows. Section II presents a stylized framework for thinking about the macroeconomic effects of public investment. Section III presents the empirical analysis used to assess the macroeconomic effect of public investment and describes the data. Section IV presents the main findings and several robustness checks of the empirical results, while Section V complements these with model simulations. Section VI concludes by summarizing the main findings and policy implications.

2. The macroeconomic effects of public investment: a stylized framework

How does public investment influence the economy? Following DeLong and Summers (2012), this section presents a stylized framework to assess the effect of public investment on output and the debt-to-GDP ratio, and to evaluate the conditions under which an increase in public investment may be self-financing.

An increase in public infrastructure investment affects the economy in two ways. First, similar to other government spending, it boosts aggregate output and employment through the short-term fiscal multiplier, whose magnitude may vary with the state of the economy (Auerbach and Gorodnichenko, 2013a, b). It may also crowd in private investment, given the highly complementary nature of infrastructure services. The increase in government spending will also affect the debt-to-GDP ratio, which may increase or decrease depending on the size of the fiscal multiplier μ and on the elasticity of revenues to output τ.

[1] Auerbach and Gorodnichenko (2013a) use forecast errors to examine how the fiscal multiplier varies with the business cycle in the USA and in a larger set of OECD economies. They do not however distinguish between government consumption and government investment.

[2] There are other features of the economy that can alter the macroeconomic effects of public investment, such as the degree of trade openness. In this study, we focus on the role of the aforementioned factors of slack, efficiency, and financing, as these have been the focus of recent policy debates on whether now is the right time to raise infrastructure investment, and if so, how it should be financed. They are also motivated by the stylized theoretical framework we present in the next section.

[3] Eden and Kraay (2014) is a notable exception. Their paper examines the causal effect of public investment on private investment and growth in a sample of low income countries.

More formally, as demonstrated in DeLong and Summers (2012), in the short term a debt-financed increase in public investment as a share of potential GDP (ΔI) leads to a change in the debt-to-potential GDP ratio (ΔD) given by

$$\Delta D = (1 - \mu\tau)\Delta I, \tag{1}$$

in which μ is the fiscal multiplier and τ is the marginal tax rate.

Over time, there is also a supply-side effect of public infrastructure investment as the productive capacity of the economy increases with the higher infrastructure capital stock. The efficiency of investment is central to determining how large this supply-side effect will be. Inefficiencies in the public investment process, such as poor project selection, implementation, and monitoring, can result in only a fraction of public investment translating into productive infrastructure, limiting the long-term output gains (Pritchett 2000; Caselli 2005).[4]

The extent to which increases in public capital can raise potential output is a key factor in determining the evolution of the public-debt-to-GDP ratio over the medium and long term. Over time, the increase in public investment will affect the debt-to-GDP ratio by affecting its annual debt-financing burden, which is equal to the difference between the real government borrowing rate (r) and the GDP growth rate (g) times the initial change in the debt-to-GDP ratio:

$$(r - g)\Delta D = (r - g)(1 - \mu\tau)\Delta I. \tag{2}$$

Whether this additional financing burden will lead to an increase in the debt-to-GDP ratio in the long term will depend on the parameters of Eq. (2) but also crucially on the long-run elasticity of output to public capital, ε, which as noted above depends in part on the efficiency of public investment. In the long term, an increase in public investment will lead to an increase in potential output (O), which will generate long-term future tax dividends:

$$\tau\Delta O = \tau\varphi y_o \Delta I, \tag{3}$$

in which ϕ is the long-term elasticity of output to public capital and y_o is the initial output-to-public capital ratio.[5] Eqs. (2) and (3) imply together that if short-term multipliers and the elasticity of output to public capital are sufficiently large, such that

$$(r - g)(1 - \mu\tau) - \tau\varphi y_o \leq 0,$$

then at the margin, an increase in public investment can be self-financing. In sum, theory suggests that public investment has both short-run demand effects as well as long-run supply effects on output and public debt, and can also crowd in private investment. But the magnitude of these effects will be shaped by factors such as cyclical conditions (which affect the fiscal multiplier), the efficiency of public investment (which mostly affects the long-term elasticity of output to public capital), and whether public investment is debt-financed or budget neutral (which can have both short- and medium-run effects, depending on whether the increase in public investment is financed by an increase in taxes or a decrease in spending). Ascertaining these magnitudes in practice is what we turn to next.

3. Empirical strategy and data

The rest of the paper examines whether the theoretical predictions regarding the macroeconomic effects of public investment are borne out in the data. To do this, we apply the statistical approach used by Auerbach and Gorodnichenko (2013a, b) as well as model simulations. To pin down the causal effects of public investment, our empirical approach identifies unanticipated changes in public investment using public investment forecasts errors. Namely, the measure of government investment shocks is the difference between the actual public investment and the public investment expected by analysts as of October of the same year. This methodology overcomes two factors that often confound the causal estimation of the effect of fiscal policy on economic performance.

First, using forecast errors eliminates the problem of "fiscal foresight" (see Forni and Gambetti 2010; Leeper, Richter, and Walker 2012; Leeper, Walker, and Yang 2013; and Ben Zeev and Pappa 2014). Agents receive news about changes in fiscal spending in advance and they may alter their consumption and investment behavior well before the changes occur. An econometrician who uses just the information contained in the change in actual public investment would be relying on an information set that is smaller than that used by economic agents, which could lead to inconsistent estimates of the effects of public investment.[6] By using forecast errors, the Auerbach and Gorodnichenko (2013a, b) methodology effectively aligns the economic agents' and the econometrician's information sets.

Second, the forecast errors we use here reduce the likelihood that the estimates capture the potentially endogenous response of fiscal policy to the state of the economy. Even if public investment shocks are unanticipated, they may still be in response to business cycle conditions: for example, public projects may be stepped up if growth turns out to be unexpectedly weak, or alternatively, they may be postponed if fiscal space is tight and revenues surprise on the downside.

[4] Public investment efficiency may also affect short-term multipliers to the extent that investment spending is diverted (e.g., into the pockets of corrupt officials) and not spent, or is used for consumption which has a lower multiplier than investment.

[5] For simplicity of formulation, the depreciation rate is assumed to be zero.

[6] Leeper, Richter, and Walker (2012) demonstrate the potentially serious econometric problems that result from fiscal foresight, showing that when agents foresee changes in fiscal policy, the resulting time series have nonfundamental representations.

For this to be a concern, however, such adjustments to public investment need to happen within the same quarter that news about the state of the economy is received (i.e. between October and December), since all information about both public investment and economic performance up until October are incorporated in the October forecasts. This is highly unlikely given the substantial lags involved in fiscal policy, particularly when it comes to capital spending. Furthermore, we later demonstrate that our findings are robust to purging the public investment shocks of forecast errors in growth.

Using these measures of unanticipated public investment shocks, we estimate two econometric specifications. First we establish the impact of public investment shocks on real GDP, the public-debt-to-GDP ratio, private investment as a share of GDP, and the unemployment rate. We then examine whether the effects of public investment vary with the state of the economy, following a growing literature that explores the effect of fiscal policy during recessions and expansions (see Auerbach and Gorodnichenko 2013a, b; Blanchard and Leigh 2013; IMF 2013; and the literature cited therein). We also investigate the role of public investment efficiency and mode of financing in shaping the macroeconomic effects of government investment.

The statistical method follows the approach proposed by Jordà (2005) to estimate impulse-response functions using local projections. This approach has been advocated by Stock and Watson (2007) and Auerbach and Gorodichencko (2013a), among others, as a flexible alternative that does not impose the dynamic restrictions embedded in vector autoregression (autoregressive-distributed lag) specifications, and is particularly suited to estimating nonlinearities in the dynamic response. The first regression specification is estimated as follows:

$$y_{i,t+k} - y_{i,t} = \alpha_i^k + \vartheta_t^k + \beta^k FE_{i,t} + \varepsilon_{i,t}^k, \tag{4}$$

in which y is the dependent variable (alternatively the log of output, the public-debt-to-GDP ratio, the private investment-to-GDP ratio, and the unemployment rate); α_i are country fixed effects, included to control for all time-invariant differences across countries (such as in countries' trend growth rates); ϑ_t are time fixed effects, included to control for global shocks such as shifts in oil prices or the global business cycle; and $FE_{i,t}$ is the forecast error of public investment of country i in year t as a share of GDP, computed as the difference between actual and forecast series. Eq. (4) is estimated for each $k=0$, . ., 4, where $k=0$ is the year of the public investment shock. Impulse-response functions are computed using the estimated coefficients β^k, while the confidence bands associated with the estimated impulse-response functions are obtained using the estimated standard errors of the coefficients β^k, based on clustered robust standard errors.

In the second specification, the response of the variable of interest is allowed to vary with the state of the economy or with the degree of public investment efficiency. The second regression specification is estimated as follows:

$$y_{i,t+k} - y_{i,t} = \alpha_i^k + \vartheta_t^k + \beta_1^k G(z_{it}) FE_{i,t} + \beta_2^k (1 - G(z_{it})) FE_{i,t} + \varepsilon_{i,t,}^k \tag{5}$$

with

$$G(z_{it}) = \frac{\exp(-\gamma z_{it})}{1 + \exp(-\gamma z_{it})}, \ \gamma > 0,$$

in which z is an indicator of the state of the economy (or the degree of public investment efficiency), normalized to have zero mean and unit variance, and $G(z_{it})$ is the corresponding smooth transition function between states (or in the degree of public investment efficiency). Our analysis uses contemporaneous GDP growth as a measure of the state of the economy. The identifying assumption is that public investment shocks do not affect the state of the economy at time t (i.e., the economy remains in either recession or expansion at the time of the shock).[7] We proxy investment efficiency with a survey-based measure of the wastefulness of government spending, from the World Economic Forum's (WEF) *Global Competitiveness Report*.[8] As in Auerbach and Gorodnichenko (2013a), $\gamma = 1.5$ is used for the analysis of recessions and expansions. For the role of public investment efficiency, we set $\gamma = 1.0$. The results do not qualitatively change if we use alternative values of γ. The main reasons for identifying the state of economy using GDP growth instead of the output gap are that the latter is unobservable and subject to substantial and frequent revisions, and as a result estimates of output gaps are typically surrounded by great uncertainty.[9]

As discussed in Auerbach and Gorodnichenko (2013a, 2013b), the local projections approach to estimating non-linear effects is equivalent to the smooth transition autoregressive (STAR) model developed by Granger and Teräsvirta (1993). The main advantage of this approach relative to estimating SVARs for each regime is that it uses a larger number of observations to compute the impulse response functions of only the dependent variables of interest, improving the stability and precision of the estimates. This estimation strategy can also more easily handle the potential correlation of the standard errors within countries, by clustering at the country level.[10]

[7] We establish the robustness of our findings to this assumption in section IV.B.

[8] We use this in the absence of a direct measure of public investment efficiency, such as the Public Investment Management Index (PIMI), for advanced economies. Similar results obtain when we use alternative proxies based on "government efficiency" or "overall quality of infrastructure," both also from the WEF's *Global Competitiveness Report*. None of these measures is perfect; the wastefulness and efficiency measures do not specifically refer to infrastructure spending, while the infrastructure measure reflects overall provision of infrastructure, which could be poor due to low efficiency but also because of inadequate spending. Berg et al. (2015) has a more extensive discussion of public investment efficiency, including problems in its measurement.

[9] As noted below, similar results are obtained when the output gap is used to identify the state of the economy.

[10] The standard errors of the estimated coefficients discussed below are even smaller if we allow for correlation in the standard errors across countries and cluster at the time period level.

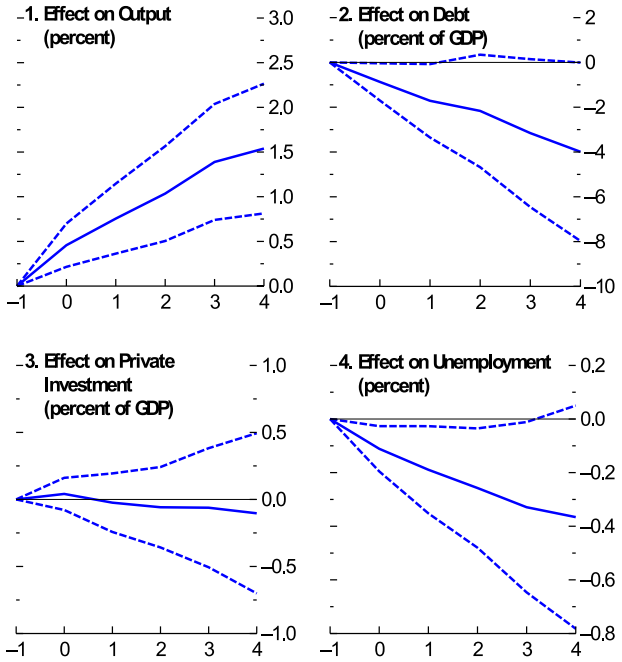

Fig. 1. Effect of public investment in advanced economies (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Shock represents an exogenous 1 percentage point of GDP increase in public investment spending.

Public investment can be financed through debt issuance, or by raising taxes or cutting other spending so that it is budget-neutral. Do the macroeconomic effects of public investment vary depending on how it is financed? To examine the role of the mode of financing, we estimate the following specification:

$$y_{i,t+k} - y_{i,t} = \alpha_i^k + \vartheta_t^k + \beta^{k+} DF_{it} FE_{i,t} + \beta^{k-}(1 - DF_{it}) FE_{i,t} + \varepsilon_{i,t}^k, \tag{6}$$

with

$DF_{it} = 1$ if public investment is debt-finance, and 0 otherwise.

The macroeconomic series used in the analysis come from the Organization for Economic Co-operation and Development's (OECD's) Statistics and Projections database, which covers an unbalanced sample of 17 OECD economies (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Japan, Korea, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States) over the period 1985–2013. The forecasts of investment spending used in the analysis are those reported in the Fall issue of the OECD's *Economic Outlook* for the same year (see Vogel 2007 and Lenain 2002 for an assessment of OECD forecasts and a comparison with forecasts prepared by the private sector). The size of the public investment shocks identified using this approach varies between –4.6 and 1.2 percentage points of GDP, with an average (median) of about –0.3 (–0.1) percentage point of GDP.

4. Empirical findings

4.1. Baseline results

The results obtained by estimating Eq. (4) show that public investment shocks have statistically significant effects on output (Fig. 1, panel 1). An unanticipated 1 percentage point of GDP increase in government investment spending increases the level of output by about 0.4 percent in the same year. Using the sample average of government investment as a percentage of output (about 3 percent of GDP), this implies short-term investment spending multipliers of about 0.4. This multiplier is consistent with other estimates of the overall government spending multiplier reported in the literature (see Coenen et al. 2012 and literature cited therein).

Our findings also suggest that public investment shocks have very long-lasting effects on output. Four years after an unanticipated shock to government investment spending of 1 percentage point of GDP, the level of real output is 1.5 percent higher, which corresponds to a medium-term fiscal multiplier of about 1.4. This finding likely reflects the expansion of the productive capacity of the economy as public investment augments the physical infrastructure stock.

Somewhat surprisingly, higher public investment spending is not associated with an increase in the debt-to-GDP ratio. The point estimates in panel 2 of the figure show that higher public investment is typically followed by a *reduction* in

the debt-to-GDP ratio, both in the short term (by about 0.9 percentage point of GDP) and in the medium term (by about 4 percentage points of GDP), but the decline in debt is statistically significant only in the short term. On average, in the advanced economies in our sample, the boost to GDP from higher government investment spending seems to be larger than the public debt taken to finance it.

There is no statistically significant effect on private investment as a share of GDP (panel 3). This result suggests the crowding in of private investment, since the level of private investment rises in tandem with the higher GDP as a result of the increase in public investment. Finally, an increase in public investment is found to reduce the unemployment rate by about 0.11 percent in the very short term and by about 0.35 percent over the medium term (panel 4).

4.1.1. The role of economic slack

The macroeconomic effects of public investment shocks are very different across economic regimes (Fig. 2). During periods of low growth, a public investment spending shock increases the level of output by about 1½ percent in the same year and by 3 percent in the medium term, but during periods of high growth the long-term effect is not statistically significantly different from zero. This finding is consistent with the growing literature on the effects of fiscal policy during recessions and expansions (see, among others, Auerbach and Gorodnichenko 2013a, 2014; Blanchard and Leigh 2013; IMF 2013). As noted above, economic regimes are identified as periods of very low growth (recessions) and very high growth (significant expansions). Periods of very low (high) growth identified also correspond to periods of large negative (positive) output gaps: during periods of very low (high) growth, the output gap varies between –0.4 and –7.2 (–1.1 and 8.5) percent of potential output, with an average output gap of –3.7 (3.5) percent. Using the output gap instead of growth rates to identify economic regimes gives qualitatively similar results. In particular, during periods of large negative output gaps, the short-term multiplier is 0.6 and is statistically significant, but when output gaps are large and positive, the output effect of public investment is 0.2 and not statistically significant.

Public investment shocks also bring about a reduction in the public-debt-to-GDP ratio during periods of low growth because of the much bigger boost in output. During periods of high growth, the point estimates suggest a rise in public debt, though the wide confidence intervals imply that the increase is not statistically significantly different from zero. The effects on private investment also differ based on the state of the economy. During low-growth periods, the increase in private investment outpaces the increase in GDP in the first few years, leading to a rise in private investment as a share of GDP. But during high-growth periods the opposite happens, suggesting the possibility of crowding out when there is less slack in the economy. Finally, public investment shocks reduce unemployment significantly during low growth periods, by about half a percentage point in the first year and by ¾ percentage point in the medium term, but do not have a material effect on unemployment rates during high-growth periods.

4.1.1.1. The role of economic efficiency. The macroeconomic effects of public investment shocks are also substantially stronger in countries with a high degree of public investment efficiency, both in the short and in the medium term (Fig. 3). In countries with high efficiency of public investment, a public investment spending shock increases the level of output by about 0.8 percent in the same year and by 2.6 percent four years after the shock. But in countries with low efficiency of public investment, the output effect is about 0.2 percent in the same year and about 0.7 percent in the medium term. As a result, although public investment shocks are found to lead to a significant medium-term reduction in the debt-to-GDP ratio in countries with high public investment efficiency, they tend to increase the debt-to-GDP ratio (albeit not in a statistically significant manner) in countries with low public investment efficiency. There is a greater boost to private investment when public investment efficiency is high, whereas private investment as a share of GDP falls when public investment efficiency is low. Finally, the effects on unemployment reduction are larger in countries with a high level of investment efficiency. Could these results be driven by some relationship between public investment efficiency and the frequency and size of public investment shocks? We find no statistically significant relationship between the measure of investment spending shocks used here and the degree of investment efficiency.[11] This suggests that the result that macroeconomic effects are larger in countries with higher investment efficiency is not driven by the fact that investment spending shocks tend to occur more frequently and to be larger in countries with higher degrees of public investment efficiency.

4.1.2. The role of Financing: Debt-financed vs. Budget-neutral public investment

The macroeconomic effects of public investment also vary depending on how it is financed. Budget-neutral public investment shocks (those which are financed by raising taxes or cutting other spending) are identified in the data as those in which the difference between the shocks to other components of the government budget and public investment shocks is greater than or equal to zero. We find that the output effects of public investment tend to be larger when public investment shocks are debt-financed than when they are budget-neutral (Fig. 4). In particular, although a debt-financed public investment shock of 1 percentage point of GDP increases the level of output by about 0.9 percent in the same year and by 2.9 percent four years after the shock, the short- and medium-term output effects of a budget-neutral public investment shock are not statistically significantly different from zero. The larger short- and medium-term output multipliers for debt-financed shocks imply that the reduction in the debt-to-GDP ratio is similar in the two types of shocks. The short-term

[11] The correlation between investment spending shocks and the degree of efficiency is –0.11.

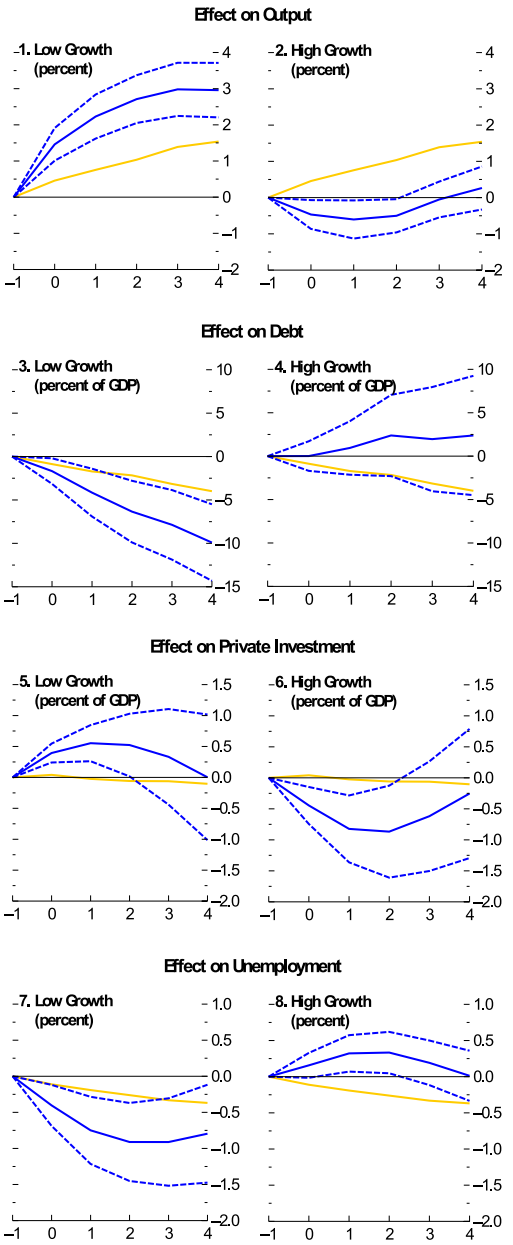

Fig. 2. Effect of public investment in advanced economies: The Role of economic conditions (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Solid yellow lines represent baseline results. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

effects on private investment are similar to those in the baseline regardless of how public investment is financed, but private investment is boosted as a share of GDP in the medium-term when public investment is debt-financed, possibly because of the larger output multipliers. Finally, and in line with the differing effects on output, the effects of public investment on unemployment are bigger when it is debt-financed than when it is budget-neutral.

It is possible that increasing debt-financed public investment in countries where debt is already high may increase sovereign risk and financing costs if the productivity of the investment is in doubt (e.g., because of poor project selection or implementation), exacerbating debt sustainability concerns. We thus examine whether public investment shocks are associated with subsequent changes in real interest rates. Within the sample of 17 advanced economies employed in the estimation, the empirical evidence suggests that historically, debt-financed public investment shocks have not led to increases in funding costs, as proxied by sovereign real interest rates (Fig. 5, panels 1 and 2).

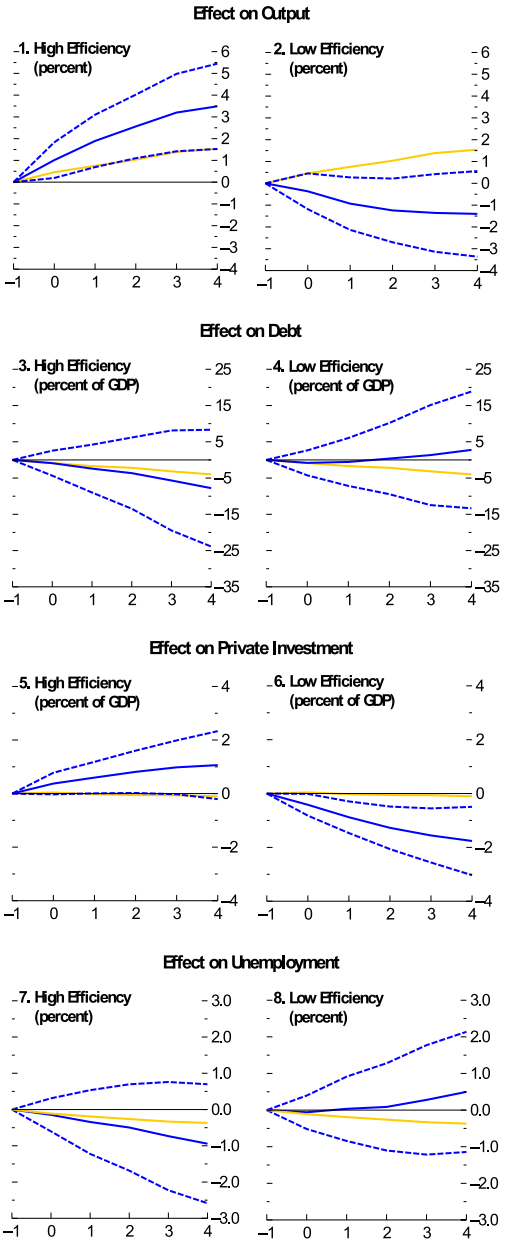

Fig. 3. Effect of public investment in advanced economies: the role of efficiency (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Solid yellow lines represent baseline results. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Moreover, an examination of whether the effects of public investment shocks on debt and output depend on the initial level of public debt yields no evidence that the effects of public investment differ materially according to the initial public-debt-to-GDP ratio (Fig. 5, panels 3 and 4). This may, in principle, reflect the fact that debt-to-GDP ratios in advanced economies were moderate during most of the sample period. However, even when we focus on country-periods of very high-debt (namely, when the debt-to-GDP ratio exceeds 100 percent of GDP—the 90th percentile of the debt-to-GDP distribution in the sample), we do not find any evidence of non-linear effects of the initial level of public debt (Fig. 5, panels 5 and 6).

4.2. Robustness checks

One of the advantages of the local projection method compared to SVARs is that it does not require that all the variables enter all equations (Ramey and Zubairy 2014). At the same, there could be feedback effects from one dependent

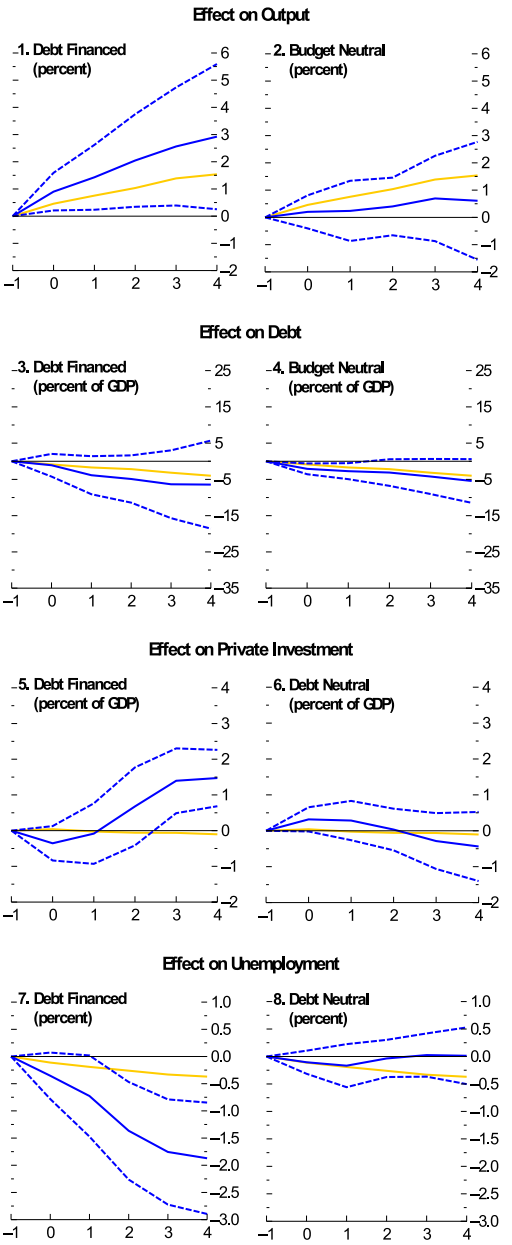

Fig. 4. Effect of public investment in advanced economies: the role of mode of financing (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Solid yellow lines represent baseline results. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

variable to another that may result in omitted variables bias. To address this concern, we estimate the following system of equations:

$$\boldsymbol{Y_{i,t+k} - Y_{i,t} = \alpha_i^k + \vartheta_t^k + \beta^k FE_{i,t} + \varphi(L)(Y_{i,t+k-1} - Y_{i,t-1}) + \delta^k(L) FE_{i,t-1} + \varepsilon_{i,t}^k} \quad (7)$$

where **Y** is a vector including the log of output, the debt-to-GDP ratio, the log of private investment and the unemployment rate. We also include lags of public investment shocks to control for possible serial correlation in the shock variable. $\varphi(L)$ and $\delta(L)$ are polynomials of order 2. The results obtained in estimating Eq. (7) are almost identical and not statistically significantly different from those reported in the baseline (Fig. 6).

Our findings are also robust to alternative measures of public investment shocks, estimation periods, and country samples. As a first robustness check, we use the forecasts of the April issue of the same year and the October issue of the previous year (instead of the forecast from October of the same year) to compute government investment forecast errors.

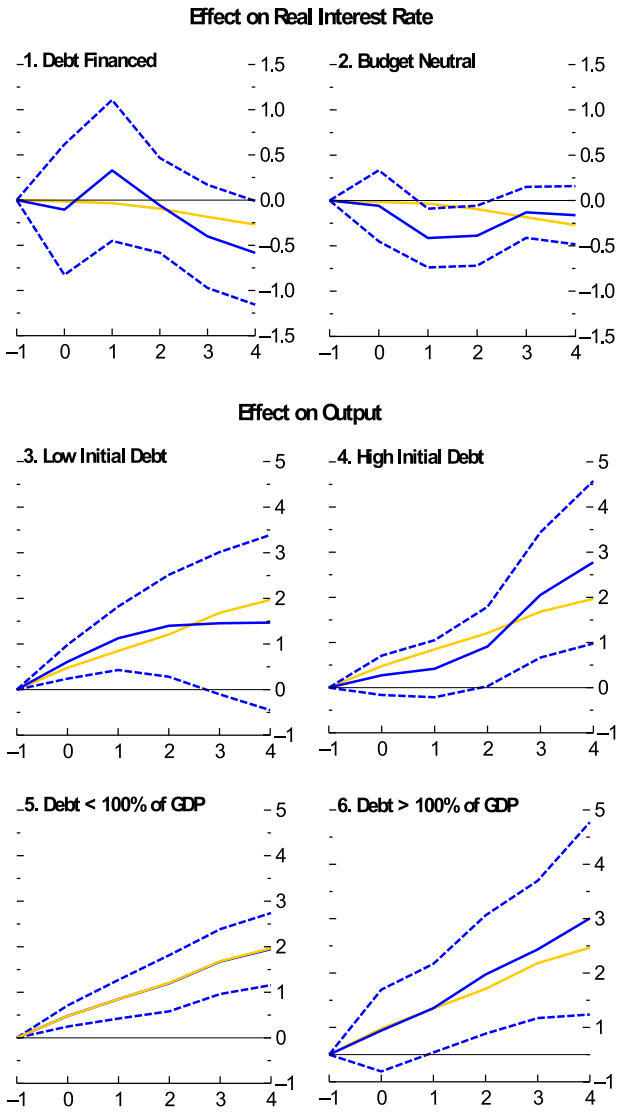

Fig. 5. Effect of Public Investment in Advanced Economies: The Role of Mode of Financing (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Solid yellow lines represent baseline results. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The results in columns 2 and 3 of Table 1 show that the response functions of real output are almost identical and not statistically significantly different from that reported in the baseline (Table 1, column 1).

As an additional robustness check, we assess whether the effects of public investment on output have changed over time. The results show that this is not the case. There has been no statistically significant change in the public investment multiplier over time in our sample of advanced economies, even though the point estimates of the output effect of public investment are somewhat larger in the post-2000 period.

A problem in the identification of public investment shocks is that they may be endogenous to output growth surprises. Indeed, whereas automatic stabilizers operate mostly via revenues and social spending, discretionary public investment spending can occur in response to output conditions. To ensure that our findings do not capture this potential reverse relationship between output and investment, we separate public investment shocks from output growth innovations.[12] The results obtained by separating public investment shocks from output growth innovations are almost identical and not statistically significantly different from those reported in the baseline (Table 1, column 6).

[12] Specifically, we regress public investment forecast errors on growth forecast errors and use the residuals from this regression as our measure of public investment shocks.

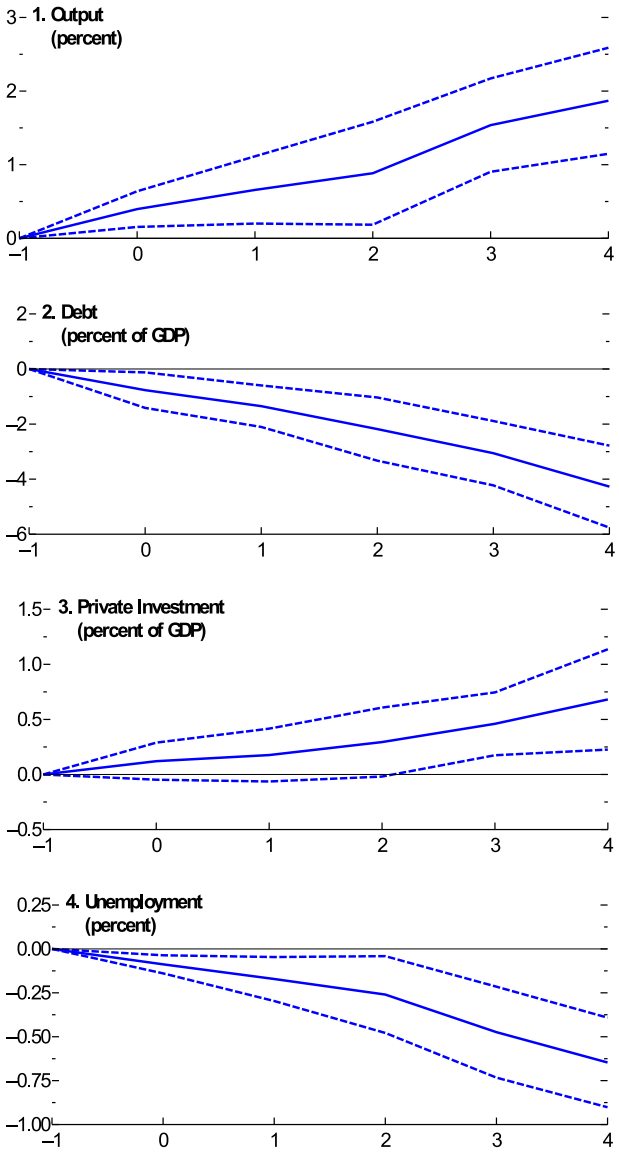

Fig. 6. The effect of public investment in advanced economies: robustness check (Years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the stock; dotted lines denote 90 percent confidence band.

Another possible problem in identifying public investment shocks is a potential systematic bias in the forecasts concerning economic variables other than public investment, with the result that the forecast errors for public investment are correlated with those for other macroeconomic variables. To address this concern, we regress the measure of public investment shocks on the forecast errors of other components of government spending, private investment, and private consumption, and use the residuals from this regression as our measure of public investment shocks. The results, presented in column 7 of Table 1, show that the response functions of output are almost identical and not statistically significantly different from that reported in the baseline.

Whether public investment has a different macroeconomic impact depending on whether the public investment shocks are positive or negative is also assessed, using the following econometric specification:

$$y_{i,t+k} - y_{i,t} = \alpha_i^k + \vartheta_t^k + \beta^{k+} D_{it} FE_{i,t} + \beta^{k-}(1 - D_{it}) FE_{i,t} + \varepsilon_{i,t}^k, \tag{8}$$

with

$$D_{it} = 1 \; if \; FE_{it} > 0 \text{ and } 0 \text{ otherwise.}$$

Table 1
Effect of public investment on output in advanced economies: robustness.

		Purging forecast errors for forecast errors in:									
	Baseline	April forecast	Previous October Forecast	Pre 2000	Post 2000	Growth	Demand components 1/	Positive Shocks	Negative Shocks	Trimmed top and bottom 1% of shocks	Top 75% and bottom 25% of shocks
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
					Impact of public investment shock on output at k=						
0	0.457	0.264	0.332	0.401	0.581	0.418	0.502	1.013	0.316	0.466	0.402
	(0.147)	(0.160)	(0.118)	(0.198)	(0.209)	(0.147)	(0.143)	(0.447)	(0.181)	(0.138)	(0.152)
1	0.755	0.581	0.697	0.582	0.948	0.702	0.844	1.240	0.584	0.740	0.675
	(0.238)	(0.216)	(0.216)	(0.301)	(0.387)	(0.241)	(0.264)	(0.619)	(0.309)	(0.232)	(0.248)
2	1.035	0.966	1.004	0.753	1.223	0.993	1.241	1.576	0.888	1.058	0.950
	(0.322)	(0.270)	(0.288)	(0.414)	(0.489)	(0.323)	(0.339)	(0.763)	(0.431)	(0.302)	(0.330)
3	1.389	1.099	1.124	1.036	1.569	1.354	1.625	1.706	1.242	1.492	1.297
	(0.394)	(0.349)	(0.330)	(0.526)	(0.575)	(0.393)	(0.405)	(0.754)	(0.547)	(0.358)	(0.400)
4	1.539	1.318	1.219	1.135	1.642	1.507	1.864	1.459	1.393	1.747	1.457
	(0.441)	(0.402)	(0.383)	(0.590)	(0.796)	(0.439)	(0.489)	(0.715)	(0.617)	(0.405)	(0.445)

Note: k=0 is the year of the public investment shock, measured by the public investment forecast error. Standard errors (in parentheses below the ceofficients) are corrected for heteroskedasticity and clustered at the country level. Sample includes 17 OECD economies for the 1985–2013 period. All regressions include a full set of country and year fixed effects.
1/ Demand components include private consumption, investment and government consumption.

The results of this exercise show that although the output effect is typically larger for positive investment shocks than for negative ones, the difference is not statistically significant (Table 1, columns 8 and 9).

Finally, we examine whether our findings are sensitive to the trimming of public investment shocks from outliers and to excluding from the analysis small unforeseen public investment shocks. Column 10 of Table 1 contains the impulse response of output when the public investment forecast errors have been trimmed from the top and bottom 1 percent of values, while in Column 11 we report the impulse response of output when we restrict the analysis to public investment forecast errors in the top 75 percent and bottom 25 percent of values. In both cases, the results are very similar and not statistically significantly different from those reported in the baseline.

Our findings are also robust to changes in the sample of countries considered. Results (available upon request) demonstrate that the impact of public investment on output ranges from 0.4 to 0.57 at time k=0, and from 1.3 to 1.9 at time k=4, when each one of the 17 economies in our baseline sample are excluded from the estimation one at a time.

The results presented in the previous section show that the short-term effects of investment spending shocks are larger in recessions than in expansions. This finding is robust to different specifications (interacting the shock with a recession dummy instead of a transition function of the state of the economy), definitions of recessions (recessions defined as periods of negative growth or when growth is below the 2013 OECD average GDP growth) and when we use lagged growth to construct the smooth transition function across states, thus relaxing the assumption that public investment shocks do not affect the state of the economy at time *t* (Fig. 7). Similarly, the finding that public investment shocks lead to larger output effects in countries with higher degree of public investment efficiency is robust to different measures. In Fig. 8, we use the public investment efficiency frontier estimated by Albino-War et al. (2014), which captures the efficiency with which a country can convert public investment into physical infrastructure stocks.

5. Model simulations

The empirical approaches in the preceding sections assessed the short- and medium-term macroeconomic effects of public investment. But those approaches are not well suited to estimating the effects of public investment shocks over longer periods (for example, more than 10 years), nor can they fully address issues that are relevant today but have little historical precedent, such as the zero floor on nominal interest rates in many advanced economies and the current environment of very low real interest rates (see Blanchard et al. 2014).[13] Therefore, to complement the empirical analysis, this section looks at the macroeconomic effects of public investment shocks using a dynamic stochastic general-equilibrium model.

The analysis uses the IMF's Globally Integrated Monetary and Fiscal model (see Kumhof and Laxton 2007; Kumhof, Muir, and Mursula 2010; Coenen et al. 2012; for a detailed description of the model). The main advantage of using such a structural model is that public investment shocks are strictly exogenous and no identification assumptions are needed. Moreover, the model presents some attractive features particularly relevant for the assessment of the impact of fiscal shocks. First, it has a highly detailed fiscal policy block. Second, it incorporates some empirically relevant channels that shape the trans-

[13] In our sample, Japan in the 1990s is the only example where public investment shocks have occurred at zero lower bound on nominal interest rates. In the model simulations the steady-state short-term real interest rate is set at 1 percent.

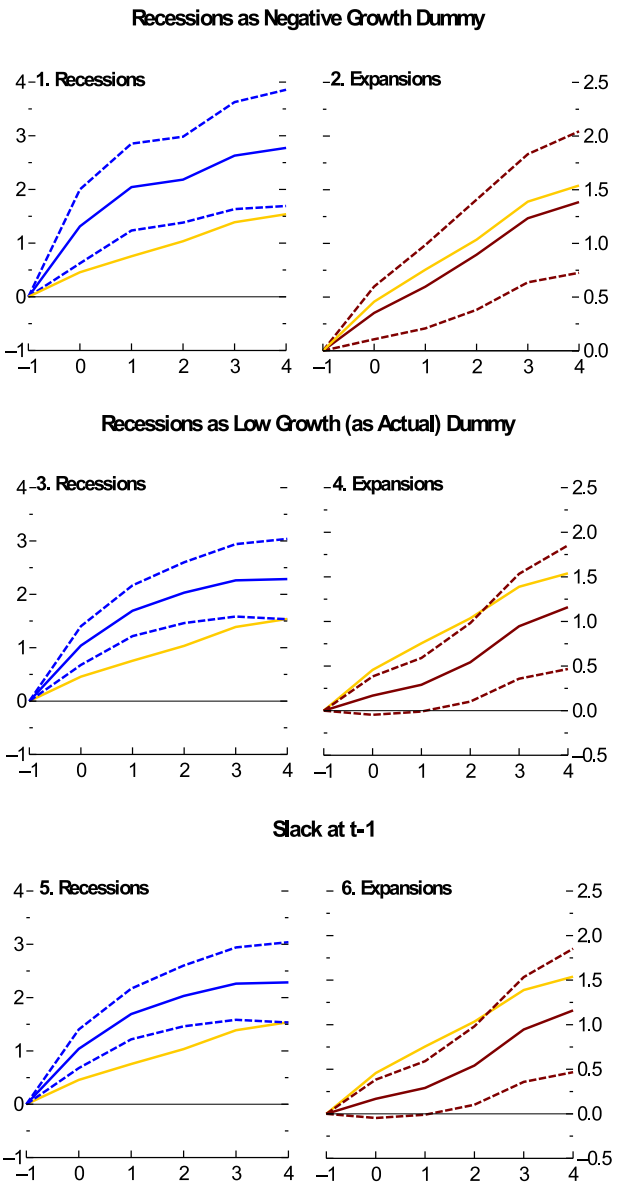

Fig. 7. Effect of public investment shocks on output, recessions versus expansions: robustness checks (Percent; years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Blue lines represent recessions; red lines represent expansions; yellow lines represent the baseline. Shock represents an exogenous 1 percentage point of GDP increase in public investment spending. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

mission of fiscal shocks (for example, it specifies that a significant share of households is liquidity constrained). Third, the model captures the effect of automatic stabilizers on both the tax and spending side.

A critical input in the model-based analysis is the elasticity of output to public capital. There is now a substantial literature, triggered by the seminal contributions of Aschauer (1989), that estimates the long-term elasticity of output to public capital. A cursory reading of the literature reveals estimates ranging widely, from large and positive to slightly negative. However, a recent meta-analysis by Bom and Ligthart (2014) of 68 of these studies shows that much of the variation in estimates can be attributed to differences in research design, including how public infrastructure capital is defined, what output measure is used, whether capital is installed at the national level or by state and local governments, the econometric specification and sample coverage, and whether endogeneity and nonstationarity are properly addressed. Controlling for these factors, Bom and Ligthart come up with a much narrower range for the estimated output elasticity of public capital. In particular, they suggest that the elasticity of output with respect to core infrastructure installed by a national government is 0.17. This is the estimated elasticity that is assumed in the baseline simulations.

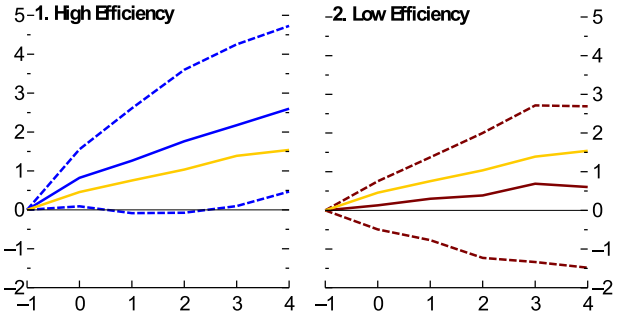

Fig. 8. Effect of public investment shocks on output, high versus low efficiency: robustness checks (Percent; years on x-axis).
Source: IMF staff calculations.
Note: t = 0 is the year of the shock; dashed lines denote 90 percent confidence bands. Blue lines represent high efficiency; red lines represent low efficiency; yellow lines represent the baseline. Shock represents an exogenous 1 percentage point of GDP increase in public investment spending. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

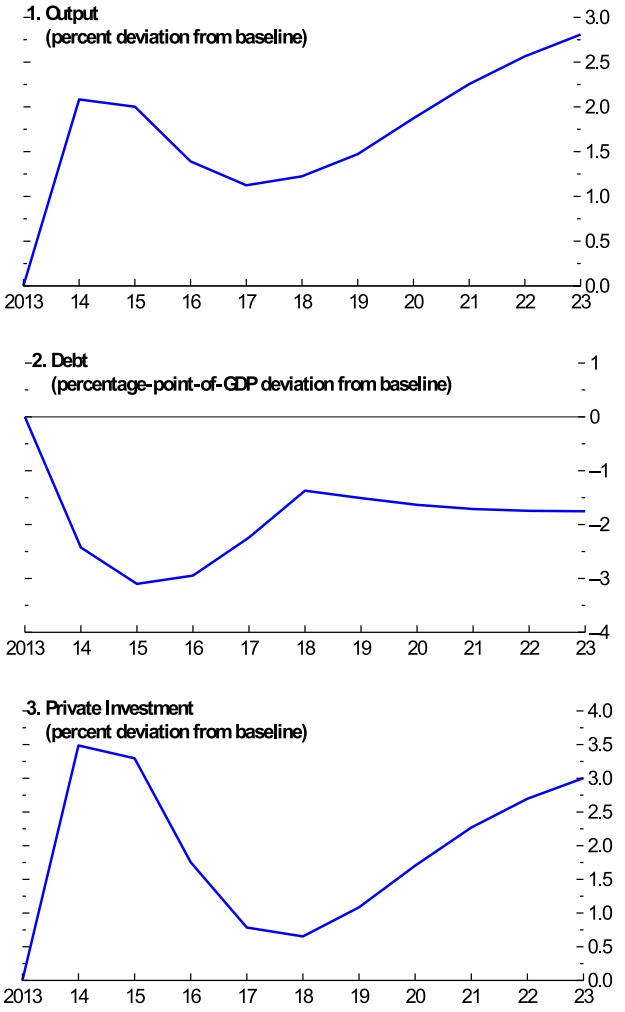

Fig. 9. Model simulations: effect of public investment in advanced economies in the current scenario.
Source: IMF staff estimates.
Note: Shock represents an exogenous 1 percentage point of GDP increase in public investment spending.

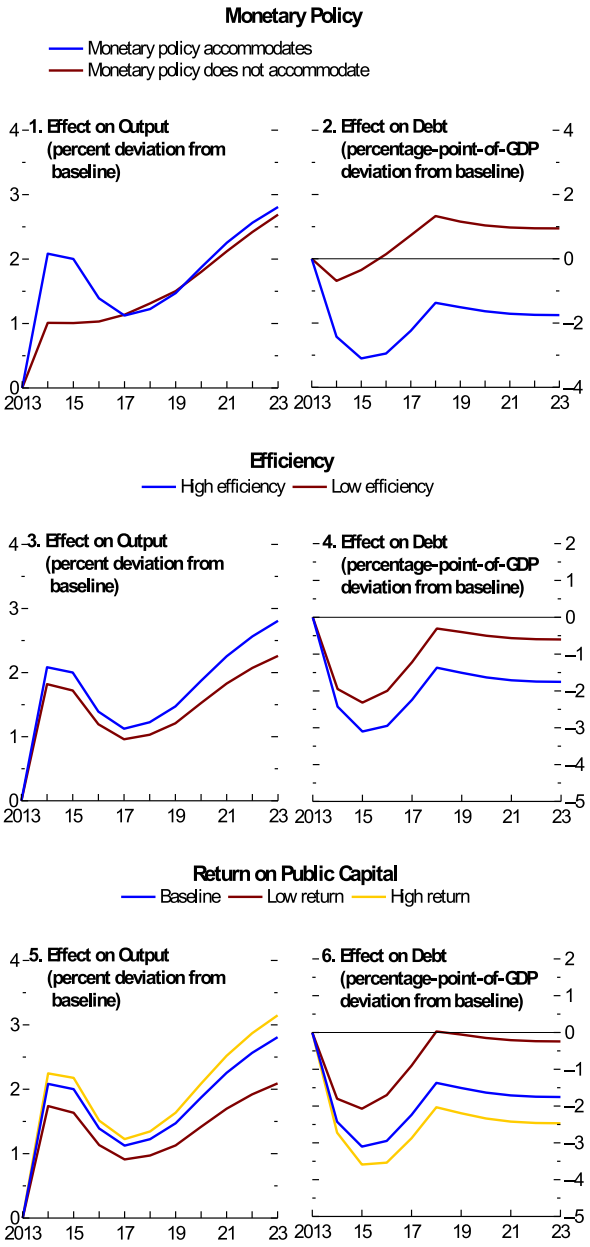

Fig. 10. Model simulations: effect of public investment in advanced economies: the role of monetary policy, efficiency, and return on public capital.
Source: IMF staff estimates.
Note: shock represents an exogenous 1 percentage point of GDP increase in public investment spending.

Since the global financial crisis, policy rates in the largest advanced economies have been near zero and are expected to remain low in the near term in light of their mediocre recoveries. The effects of public investment shocks under these conditions are examined through a simulation of the macroeconomic response of output, the public-debt-to-GDP ratio, and private investment to a 1 percent of GDP increase in public investment, assuming that monetary policy rates stay close to zero for two years. There are two main reasons to assume that policy rates stay near zero for two years. First, such an assumption is in line with market expectations about policy rates for most large advanced economies. Second, in the model, the only way the central bank can stabilize output and inflation is by cutting nominal interest rates. When the option of cutting interest rates is removed for a longer period—for example, three or more years—the model generates unstable macroeconomic dynamics, which complicates the computation of simulation results.

The results of this simulation suggest that a 1 percent of GDP permanent increase in public investment increases output by about 2 percent in the same year. Output declines in the third year after the shock as monetary policy normalizes, then

increases to 2.5 percent over the long term because of the resulting higher stock of public capital (Fig. 9, panel 1). These results are consistent with recent papers that have used theoretical models to analyze the effect of fiscal stimulus in a liquidity trap. Hall (2009) finds a short- term output multiplies close to 1.7 at a zero nominal interest rate. Christiano et al. (2011) and Eggerston (2011) find even stronger effect at the zero lower bound, with multipliers ranging between 2 and 2.5.

Similarly, the permanent increase in public investment boosts private investment both in the short and in the long term (Fig. 9, panel 3). The large output effects imply that the debt-to-GDP ratio declines, by about 3 percentage points of GDP three years after the shock, after which it increases somewhat, stabilizing at about 1.5 percentage points of GDP below the baseline five years after the shock.[14]

How different would the results be under normal conditions of less slack and an immediate monetary policy response to the increase in public investment? In this case, the short-term output effects would be much smaller. As a result, the debt-to-GDP ratio would eventually rise, stabilizing at a level 1.5 percentage points of GDP higher than the baseline (Fig. 10, panels 1 and 2). These results are broadly consistent with the empirical evidence in the previous section.

These simulations implicitly assume that public investment is fully efficient, that is, that each dollar invested translates into productive public capital. However, it is likely that in countries with a lower degree of investment efficiency, the resulting output effects are smaller. The simulations presented in Fig. 9, panels 3 and 4, confirm and quantify these results. In countries with a lower degree of investment efficiency, a 1 percentage point of GDP increase in public investment increases output by about 2.2 percent in the long term, compared with about 2.8 percent in countries where public investment is fully efficient. As a result, in countries with a low degree of investment efficiency, the debt-to-GDP ratio would decline less than in countries with full investment efficiency.

Finally, the simulations presented in panels 5 and 6 of Fig. 9 illustrate how different assumptions regarding the long-term return of public investment (the elasticity of output to public capital) affect the results. In particular, they show that the higher the return on public capital and the productivity of investment, the larger the long-term output effect of increases in public investment, and the decline in the debt-to-GDP ratio.

6. Conclusions and policy implications

We examine the macroeconomic impact of increased public investment, and find that such investment raises output in both the short and long term, crowds in private investment, and reduces unemployment, with limited effect on the public debt ratio. We also find that these effects vary with a number of mediating factors. The effects of public investment are particularly strong when there is slack in the economy and monetary accommodation. In such cases, the boost to output from higher government investment may exceed the debt issued to finance the investment. Government projects are more effective in boosting output in countries with higher efficiency of public investment. Finally, the mode of financing investment matters. We find suggestive evidence that debt-financed projects have larger expansionary effects than budget-neutral investments financed by raising taxes or cutting other government spending.

Our findings suggest that for economies with clearly identified infrastructure needs and efficient public investment processes and where there is economic slack and monetary accommodation, there is a strong case for increasing public infrastructure investment. Moreover, evidence suggests that increasing public infrastructure investment will be particularly effective in providing a fillip to aggregate demand and expanding productive capacity in the long run, without raising the debt-to-GDP ratio, if it is debt financed.

Finally, our results show how critical increasing investment efficiency is to mitigating the possible trade-off between higher output and higher public-debt-to-GDP ratios. Thus a key priority in many economies, particularly in those with relatively low efficiency of public investment, should be to raise the quality of infrastructure investment by improving the public investment process.

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References

Albino-War, M., Cerovic, S., Flores, J.C., Grigoli, F., Kapsoli, J., Qu, H., Said, Y., Shukurov, B., Sommer, M., Yoon, S., 2014. Making the Most of Public Investment in Oil-Exporting Countries. International Monetary Fund, Washington Staff Discussion Note 14/10.

Aschauer, D.A., 1989. Is public expenditure productive? J. Monetary Econ. 23 (2), 177–200.

Auerbach, A., Gorodnichenko, Y., 2013a. Fiscal multipliers in recession and expansion. In: Alberto, A., Giavazzi, F. (Eds.), Fiscal Policy After the Financial Crisis. NBER Books, National Bureau of Economic Research, Inc., Cambridge, Massachusetts.

[14] The public investment shock is debt financed for the first five years. The debt-to-GDP ratio is stabilized and general transfers adjust to satisfy the fiscal rule afterward. The model needs to include a fiscal rule to ensure that it generates stable macroeconomic dynamics. Note, however, that given the large output effects, general transfers end up at a level higher than what prevailed in the absence of the shock.

Auerbach, A., Gorodnichenko, Y., 2013b. Measuring the output responses to fiscal policy. Am. Econ. J. 4 (2), 1–27.
Auerbach, A., Gorodnichenko, Y., 2014. Fiscal Multipliers in Japan. National Bureau of Economic Research, Cambridge, Massachusetts NBER Working Paper 19911.
Ben Zeev, N., Pappa, E., 2014. Chronicle of a War Foretold: The Macroeconomic Effects of Anticipated Defense Spending Shocks. Centre for Economic Policy Research, London CEPR Discussion Paper 9948.
Berg, A., Buffie, E.F., Pattillo, C., Portillo, R., Presbitero, A., Zanna, F., 2015. Some Misconceptions about Public Investment Efficiency and Growth IMF Working Paper.
Blanchard, O.J., Furceri, D., Pescatori, A., 2014. A prolonged period of low real interest rates?. In: Coen, T., Baldwin, R. (Eds.), Secular Stagnation: Facts, Causes and Cures. Centre for Economic Policy Research, London.
Blanchard, O.J., Leigh, D., 2013. Growth forecast errors and fiscal multipliers. Am. Econ. Rev. 103 (3), 117–120.
Blanchard, O.J., Perotti, R., 2002. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. Quart. J. Econ. 107 (4), 1329–1368.
Bom, P.R., Ligthart, J.E., 2014. What have we learned from three decades of research on the productivity of public capital? J. Econ. Surv. 28 (5), 889–916.
Caselli, F., 2005. Accounting for Cross-Country Income Differences. National Bureau of Economic Research Working Paper 10828.
Christiano, L., Eichenbaum, M., Rebelo, S., 2011. When is the government spending multiplier large? J. Polit. Econ. 119 (1), 78–121.
Coenen, G., Erceg, C.J., Freedman, C., Furceri, D., Kumhof, M., Lalonde, R., Laxton, D., Lindé, J., Mourougane, A., Muir, D., Mursula, S., de Resende, C., Roberts, J., Roeger, W., Snudden, S., Trabandt, M., in't Veld, J., 2012. Effects of fiscal stimulus in structural models. Am. Econ. J. 4 (1), 22–68.
Cogan, J.F., Cwik, T., Taylor, J.B., Wieland, V., 2010. New Keynesian versus Old Keynesian government spending multipliers. J. Econ. Dyn. Control 34 (3), 281–295.
DeLong, Jrd., Summers, L.H., 2012. Fiscal policy in a depressed economy. Brook. Papers Econ. Activity 44 (1), 233–297.
Eden, M., Kraay, A., 2014. Crowding In and the Returns to Government Investment in Low-Income Countries World Bank Policy Research Working Paper 6781.
Eggertsson, G.B., 2011. What fiscal policy is effective at zero interest rates?. In: Daron, A., Woodford, M. (Eds.). In: *NBER Macroeconomics Annua*l 2010, Vol. 25. University of Chicago Press, Chicago, pp. 59–112.
Erceg, C.J., Lindé, J., 2010a. Is There a Fiscal Free Lunch in a Liquidity Trap? Board of Governors of the Federal Reserve System International Finance Discussion Paper 1003.
Erceg, C.J., Lindé, J., 2010b. Asymmetric shocks in a currency union with monetary and fiscal handcuffs. In: Richard, C., Giavazzi, F. (Eds.). In: NBER National Seminar on Macroeconomics 2010, Vol. 7. University of Chicago Press, Chicago, pp. 95–135.
European Commission. An Investment Plan for Europe http://ec.europa.eu/priorities/jobs-growth-investment/plan/index_en.htm.
Favero, C., Giavazzi, F., 2009. How Large are the Effects of Tax Changes?. National Bureau of Economic Research Working Paper 15303.
Forni, M., Gambetti, L., 2010. Fiscal Foresight and the Effects of Government Spending. Centre for Economic Policy Research Discussion Paper 7840.
Freedman, C., Kumhof, M., Laxton, D., Muir, D., Mursula, S., 2010. Global effect of fiscal stimulus during the crisis. J. Monetary Econ. 57, 506–526.
Granger, C.W.J., Teräsvirta, T., 1993. Modelling Nonlinear Economic Relationships. Oxford University Press, New York.
Hall, R.E., 2009. By How Much Does GDP Rise if the Government Buys More Output?. National Bureau of Economic Research Working Paper 15496.
International Monetary Fund (IMF), 2013. Reassessing the Role and Modalities of Fiscal Policy in Advanced Economies IMF Policy Paper, Washington.
Jordà, Ò., 2005. Estimation and inference of impulse responses by local projections. Am. Econ. Rev. 95 (1), 161–182.
Kraay, A., 2012. How large is the government spending multiplier? Evidence from world bank lending. Quart. J. Econ. 127 (2), 829–887.
Kraay, A., 2014. Government spending multipliers in developing countries: evidence from lending by official creditors. Am. Econ. J. 6 (4), 170–208.
Kumhof, M., Laxton, D., 2007. A Party without a Hangover? On the Effects of U.S. Government Deficits. International Monetary Fund Working Paper 07/202.
Kumhof, M., Muir, D., Mursula, S., 2010. The Global Integrated Monetary and Fiscal Model (GIMF)—Theoretical Structure. International Monetary Fund Working Paper 10/34.
Leeper, E.M., Richter, A.W., Walker, T.B., 2012. Quantitative effects of fiscal foresight. Am. Econ. J. 4 (2), 115–144.
Leeper, E.M., Walker, T.B., Yang, S.-C.S., 2013. Fiscal foresight and information flows. Econometrica 81 (3), 1115–1145.
Lenain, P., 2002. What Is the Track Record of OECD Economic Projections? Organisation for Economic Co-operation and Development, Paris.
Owyang, M.T., Ramey, V.A., Zubairy, S., 2013. Are government spending multipliers greater during periods of slack? Evidence from twentieth-century historical data. Am. Econ. Rev. 103 (3), 129–134.
Pritchett, L., 2000. The tyranny of concepts: CUDIE (Cumulated, Depreciated, Investment Effort) is not capital. J. Econ. Growth 5 (4), 361–384.
Ramey, V.A., Zubairy, S., 2014. Government Spending Multipliers in Good Times and in Bad: Evidence from U.S. Historical Data. National Bureau of Economic Research, Cambridge, Massachusetts NBER Working Paper 20719.
Romer, C., Romer, D., 2010. The macroeconomic effects of tax changes: estimates based on a new measure of fiscal shocks. Am. Econ. Rev. 100 (3), 763–801.
Romp, W., de Haan, J., 2007. Public capital and economic growth: a critical survey. Perspectiven der Wirtschaftspolitik 8 (S1), 6–52.
Stock, J.H., Watson, M.W., 2007. Why has U.S. inflation become harder to forecast? J. Money Credit Bank. 39 (S1), 3–33.
Straub, S., 2011. Infrastructure and development: a critical appraisal of the macro-level literature. J. Develop. Stud. 47 (5), 683–708.
Summers, L.H., 2013. Remarks in honor of Stanley Fischer. Fourteenth Jacques Polak Annual Research Conference, International Monetary Fund November 7–8.
Teulings, C., Baldwin, R. (Eds.), 2014, Secular Stagnation: Facts, Causes and Cures. Centre for Economic Policy Research, London.
Vogel, L., 2007. How Do the OECD Growth Projections for the G7 Economies Perform? A Post-Mortem. Organisation for Economic Co-operation and Development Working Paper 573.
Woodford, M., 2011. Simple analytics of the government expenditure multiplier. Am. Econ. J. 3 (1), 1–35.