Online Annex 2.1. The Macroeconomic Effects of Public Investment: A Model-based Analysis

Global growth remains fragile, inflation rates are below targets in many economies, government borrowing costs are at historical lows, and the global economy is awash with debt (public and private). Is it time for an efficient public investment push? How large and long-lasting would such a surge in public investment need to be to "move the needle" on growth, inflation, and interest rates? A model-based analysis shows that efficient public investment, if persistent, can lift growth, inflation, and interest rates; inefficient investment, however, will only bring modest macroeconomic effects while public debt-to-GDP ratio will surge.

This annex relies on a revised model based on Traum and Yang (2015) to quantify the macroeconomic effects of a large and long-lasting increase in public investment and to illustrate the role of investment efficiency. This closed-economy dynamic stochastic general equilibrium model of the world follows closely the New Keynesian structure of Smets and Wouters (2003, 2007) and has a detailed fiscal sector, including distorting taxation of consumption, labor, and capital income; transfers to households; productive and unproductive government spending; and endogenous public debt accumulation. In addition to standard forward-looking households with rational expectations, the model includes liquidity-constrained households to account for varying responses to fiscal policy. Monetary policy follows a Taylor principle with interest rate smoothing—that is, responding gradually to inflation—and a small response to output gaps. Simulation results from the model are also compared with those of the IMF's Global Integrated Monetary and Fiscal model (GIMF), a six-region open-economy model that captures the interlinkages across countries at the global level.

The model is used to simulate the effects of two public investment–package scenarios: an efficient investment scaling-up (baseline) and a less-efficient one. Each scenario considers three types of public investment: infrastructure, low-carbon technologies, and other UN Sustainable Development Goals (SDGs). At the global level, baseline simulations take an initial investment of 1.3 percent of global GDP (comprising 0.5 percent of GDP on infrastructure, 0.6 percent on low-carbon technologies, and 0.2 percent toward other SDGs for access to clean water, sanitation, and electricity) based on estimates from the G20 Global Infrastructure Outlook,[1] the Global Commission on Adaptation, and the October 2019 Fiscal Monitor. The investments gradually decline over time to half of their initial values by year twenty. The cumulative public investment injection over 20 years is 18 percent of global GDP. At the EU level, the simulations assume an initial public investment increase of 0.6 percent of the EU's GDP, comprising 0.35 percent on infrastructure and 0.25 percent on low-carbon technologies. For illustrative purposes, the green investment needs of 0.25 percent of EU's GDP is assumed to be new financing rather than from rebalanced EU budget expenditure. Also, the two types of investments are assumed to gradually decline over time.

Global Public Investment Needs

Baseline Simulations: An Efficient Investment Scaling-Up

The model is calibrated to match the weighted average of fiscal variables at the global economy level in 2019, with an initial public debt of 84 percent of GDP and public investment of 3.8 percent of GDP per year (before the global public investment surge).[2] The slope of the Phillips curve is calibrated to match

[1] "Global Infrastructure Outlook," https://outlook.gihub.org/.

[2] The weighted average global public debt-to-GDP and public investment-to-GDP ratios are calculated from data on general government gross debt, public gross capital formation, and GDP across countries in the World Economic Outlook database. The weights are computed as a country's nominal GDP in U.S. dollars divided by the sum of all countries' GDPs.

the empirical evidence for eight major economies in Dees and others (2014). The analysis assumes that only the consumption tax rate responds to deviations of debt from its steady-state level. The magnitude of response is small but sufficient to maintain debt sustainability.

The three types of public investment differ in their effectiveness in raising the productivity of private capital and labor, leading to different cumulative output multipliers (Online Annex Table 2.1.1).[3] Infrastructure is the most productive investment with a two-year cumulative multiplier of 0.7 (twenty-year cumulative multiplier of 1.7), roughly matching the cross-country estimates in Ilzetzki and others (2013). For investment in other SDGs, the calibration yields a twenty-year cumulative multiplier of 1.4 because they have lower overall network externalities. Last, considering the considerable uncertainty around the size of green investment multipliers, the calibration assumes a twenty-year cumulative multiplier of around 1.0—the average of long-term output multipliers for general public investment in the literature (Ramey 2019).

The stacked columns in panel 1 of Online Annex Figure 2.1.1 present impulse responses of GDP, inflation, the real interest rate, and public debt over the 20-year horizon for the baseline simulations relative to the path without the investment increase. In the short term, GDP experiences an inverted hump-shaped response as the private sector activity is crowded out initially, owing to higher real interest rates. As the productive public capital gradually builds up over time, it raises the productivity of private capital and crowds in private investment. The positive GDP effects also become stronger over time as the stock of productive public capital increases.

On the nominal side, the public investment package increases inflation, as shown in panel 2. In the first year, inflation jumps by 1 percentage point. More public investment adds to aggregate demand, putting upward pressure on inflation. This positive effect on inflation diminishes over time as the monetary authorities partly respond to the inflation increase by raising the policy rate. In addition, as investment is transformed to productive public capital, it expands private production capacity, offsetting the inflationary pressure from higher demand.

There is a small positive impact on the real interest rate, as shown in panel 3. Although intuition suggests that the injection of a persistent large fiscal stimulus should significantly add to aggregate demand (boosting the real interest rate), the investment from fiscal stimulus also expands the production capacity from higher public capital, which would ease such pressures on interest rates. From the perspective of monetary policy, the response of the nominal interest rate closely follows inflation dynamics on average, which suggests the real interest rate only responds slightly in the equilibrium.

Since the scaling up of public investment is debt financed and output multipliers are less than 1.0 in the first few years, the stock of public debt increases over the short and medium terms. In the baseline simulations, public debt increases by about 9 percentage points of GDP in 20 years (shown in panel 4). The magnitude of the debt increase is half of the cumulative public investment injection.

An Alternative Scenario: Less Efficient Investment Scaling-Up

Public investment efficiency matters for fiscal multipliers (Shen, Yang, and Zanna 2018), and because of capacity constraint it is a major concern when investment is scaled up quickly and sizably. To highlight

[3] In the Traum-Yang model, public and private capital are complements. This assumption is reasonable for infrastructure and other SDG investment. However, it is not clear whether public investment in low-carbon technologies should complement existing private capital (which might be in coal, fossil fuels, and so on). Further research is needed to study the complementarity or substitutability of green investment with existing private capital. Also, carbon taxation will likely accelerate the depreciation of existing capital, raising the marginal product of new capital.

the role of investment efficiency, an alternative simulation allows the marginal public investment efficiency on new additional investment to be low.[4]

The baseline simulations assume that a $1.0 of additional investment can convert to $0.9 of public capital. The alternative simulation assumes that the marginal investment efficiency is at 0.4, matching the 25th percentile efficiency loss at the global level (IMF 2015), implying an average investment efficiency of 0.8. The black lines in the four charts of Online Annex Figure 2.1.1 are the aggregate impulse responses of the three types of investment in the alternative simulation. The last three columns of Online Annex Table 2.1.1 present the cumulative output multipliers for this alternative simulation. Relative to baseline simulations, even the twenty-year cumulative output multipliers for infrastructure investment are below 1.0. In that case, the smaller rise in GDP would be accompanied by much higher public debt, as shown by the black solid line in panel 4 of Online Annex Figure 2.1.1.

Comparison to Simulation Results using Global Integrated Monetary and Fiscal Model

To check the robustness of results to an alternative modeling approach, baseline simulations are compared to the results obtained from IMF's GIMF model.[5] Different from the closed-economy model of Traum and Yang (2015), GIMF is a multicountry structural dynamic general equilibrium model featuring six regions. Its household sector consists of forward-looking optimizing agents and liquidity-constrained households who spend all their available income every period. GIMF is based on an overlapping generations (OLG) framework, à la Blanchard-Weil-Yaari (Yarri 1965, Blanchard 1985, and Weil 1989). Furthermore, the presence of overlapping generations households breaks the Ricardian equivalence, beyond the inclusion of liquidity constrained households. The calibration of the elasticity of public capital from an increase in global infrastructure investment matches the average of elasticities from advanced countries and emerging market economies.[6]

The effects of the public investment scaling-up scenarios using GIMF match closely that of the baseline simulations. Panels 1-3 of Online Annex Figure 2.1.2 compare the GDP responses for each type of investment under the two models, and panels 4-6 compare the aggregate responses of inflation, the real interest rate, and public debt across the three types of investment. At a glance, the baseline simulations largely yield the same qualitative results as in the GIMF. In particular, the output responses of infrastructure investment are quantitatively similar between the two models' results (panel 1). In the first year, the GIMF predicts a 0.7 percent increase in output, while the baseline simulation predicts a 0.5 percent increase. Over the long term, both models predict an output increase of about 1 percent 20 years after the initial investment increase. The slight differences between the two models in the beginning years can be explained by the crowding-out effects in Traum and Yang (2015). The GIMF predicts an immediate crowding-in because the negative wealth effect from increasing government spending in a model with a finite planning horizon is much weaker than that in New Keynesian or neoclassical growth models with infinitely-lived agents.[7] Both models predict crowding-in effects in the long term as more productive public capital encourages private investment.

[4] Berg and others (2019) show that a lower steady-state public investment efficiency does not lower the growth impact of public investment because lower steady-state efficiency implies a lower capital stock, which has a higher marginal product of capital than is the case with a higher efficiency. Thus, to capture the effect of a lower efficiency when investment is scaled up quickly and sizably, the simulation imposes a lower marginal efficiency, instead of a lower steady-state efficiency.

[5] See Kumhof and others (2010) for the model structure of the GIMF. Michal Andrle in the Research Department conducted the simulations with the GIMF model, and Rachel Zhang provided outstanding research assistance.

[6] The calibration is largely based on the meta-analysis in Ligthart and Suarez (2011) and some results are adjusted using the country public investment efficiency assessment in Gupta and others (2014).

[7] The crowding-out effects of government spending (including government consumption and public investment) are supported by several empirical papers (for example, Ramey and Shapiro 1998, Blanchard and Perotti 2002, Mountford and Uhlig 2009, and

For inflation, both models yield positive short-term responses, and the effects wane over time (panel 4). The real interest rate behaves slightly differently on impact: the baseline simulations imply an initial decline before rising, while the GIMF results in an immediate positive response (panel 5). This difference is because the baseline simulations assume a higher degree of interest smoothing than the GIMF. While both models feature Taylor-type interest rate rules, the initial nominal interest rate response is smaller in the baseline simulations because of a higher degree of interest smoothing. Also, unlike the GIMF, which has the interest rate rule respond to *future* and current inflation, the Traum-Yang model only responds to current inflation. Despite the very different initial predictions in the first year, the magnitude of the real interest rate increase for the medium and longer terms are broadly similar in the models. Finally, both models predict an increase in debt ratio over time (panel 6).

European Union Investment

The macroeconomic effects of a surge in public investment are particularly relevant in Europe. The European Commission in January 2020 proposed to mobilize and then spend €1 trillion for sustainable investment over 2021–27—assuming large national cofinancing, subsidized loans from the European Investment Bank, and private sector investment. The allocation from the EU budget is about 0.25 percent of GDP per year, which is used in the following simulations. In addition, the package includes an initial increase of 0.35 percent of the EU's GDP in infrastructure, reflecting the European Commission's plan to increase public investment in general over the next decade.

To pursue the simulations for the EU, the Traum-Yang model is run separately with a calibration that matches the weighted average fiscal variables of the EU in 2019 with an initial public debt set at 84 percent of GDP. The slope of the Phillips curve and the interest rate smoothing parameter in the monetary policy rule are calibrated to those estimated in Dees and others (2014) for three euro-area economies in their sample. Again, the two areas of public investment (infrastructure and green investment) would have an initial injection of 0.6 percent of GDP, which declines gradually over time. The efficiency of investment in these two areas is assumed to be identical to those used in the global model. As a result, the implied multipliers are similar (Online Annex Table 2.1.1).

Online Annex Figure 2.1.3, panels 1-4 present the effects of a public investment increase in the EU. The stacked columns show the impulse responses under the efficient public investment assumption, and black solid lines are the aggregate responses under the lower-efficiency scenario. The results of GDP, inflation, the real interest rate, and the public debt-to-GDP ratio are qualitatively the same as those in the baseline simulations, but the magnitudes are smaller because of a smaller-scale increase in public investment. The public investment package in the EU increases inflation by 0.4 percentage points in the first year, and the effects diminish over time (panel 2). Under the efficient public investment assumption, the public debt-to-GDP ratio only increases by slightly less than 2 percent of GDP, while it increases by almost 6 percent of GDP under the low-efficiency assumption (panel 4).[8]

Ramey 2011). Also, Boehm (forthcoming) uses a panel of OECD countries to estimate specifically for public investment effects and finds that private investment responds negatively in the short term to a public investment increase.

[8] In addition to the GIMF model, the implication of the Traum-Yang model has been compared to the simulations of a government spending shock in Gros and Capolongo (2019). To make the results comparable, the size of the government spending increase is reduced to a one-quarter shock equal to 1 percent of GDP. The main conclusion of Gros and Capolongo (2019) is that fiscal stimulus is likely to be ineffective in raising inflation in the euro area. The simulation with the Traum-Yang model also generates a small inflation response: a peak inflation of about 6 basis points, compared to the mean peak responses of 4 basis points across the ten models used in Gros and Capolongo (2019). In the longer horizon, both the average responses of the ten models presented in Gros and Gapolongo (2019) and the responses of the Traum-Yang model predict that inflation returns to the targets quickly (D. Gros and A. Capolongo, "Fiscal Policy Cannot Save the ECB," *VOX* (blog), CEPR Policy Portal, December 3, 2019. https://voxeu.org/article/fiscal-policy-cannot-save-ecb).

Online Annex Table 2.1.1. Cumulative Output Multipliers

	Baseline Simulations			Low Public Investment Efficiency		
	2-year	10-year	20-year	2-year	10-year	20-year
Infrastructure	0.7	1.1	1.7	0.6	0.6	0.8
Other SDGs	0.7	0.9	1.4	0.6	0.5	0.7
Low-carbon technology	0.6	0.7	1.0	0.5	0.5	0.5

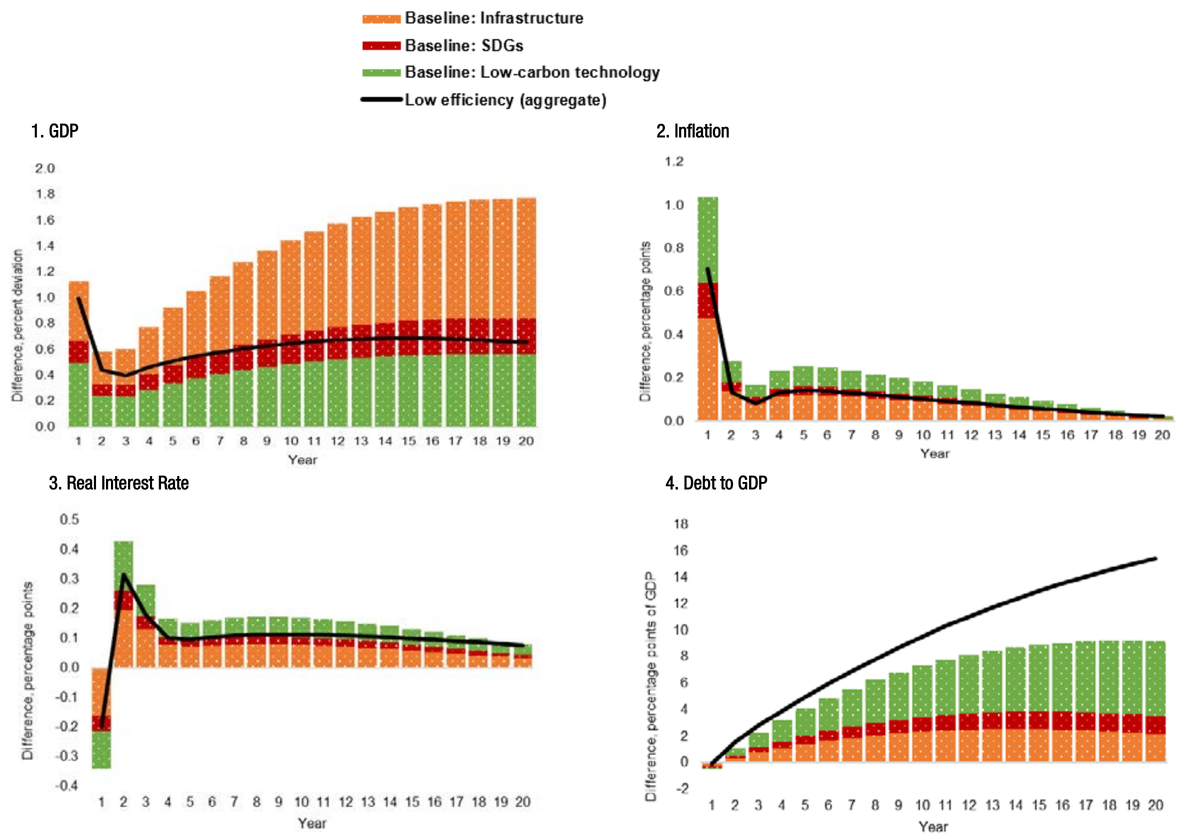
Source: IMF staff estimates.

Note: SDGs = Sustainable Development Goals.

Online Annex Figure 2.1.1. Simulated Macroeconomic Effects of a Global Public Investment Increase

(Difference in percent or percentage points relative to no public investment increase)

A large sustained public investment could lift output, inflation, and the real interest rate, and cause a mild increase in the debt-to-GDP ratio if investment is efficient.



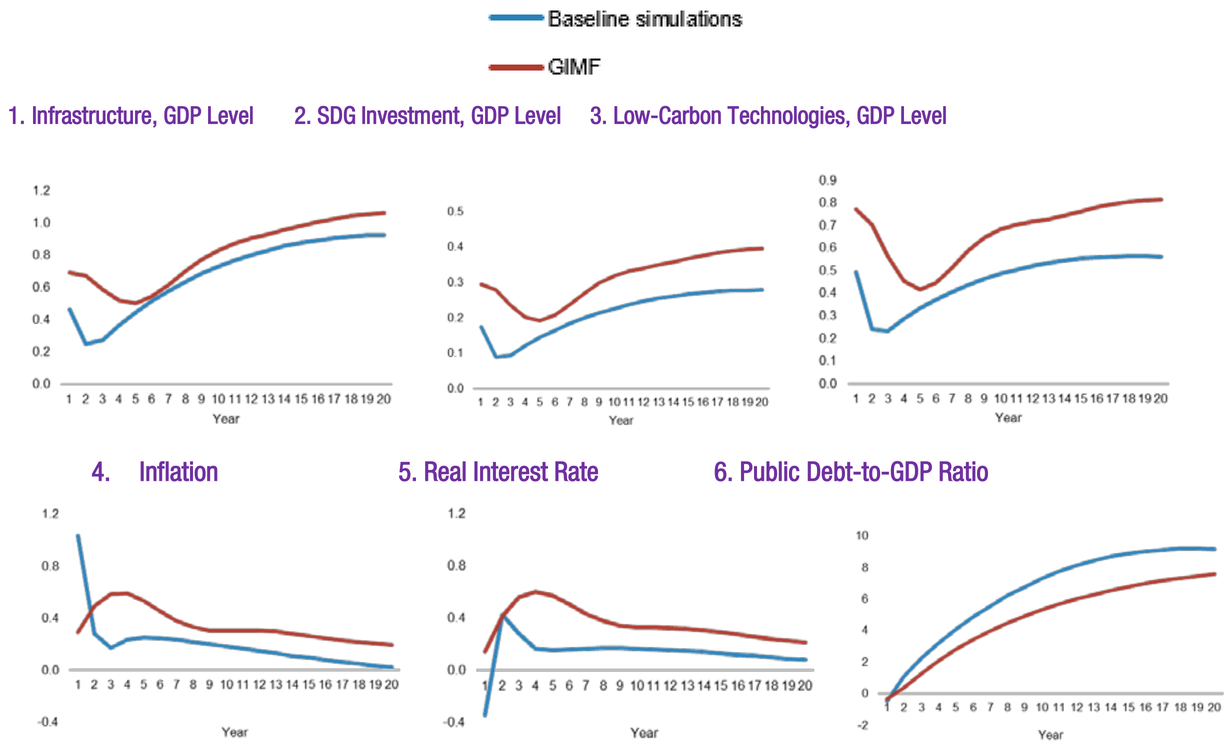
Source: IMF staff estimates based on a revised version of Traum & Yang (2015).

Note: Impulse responses to a persistent increase in three types of public investment: The initial increase is 0.5 percent of global GDP in infrastructure, 0.6 percent of global GDP in low-carbon technologies, and 0.2 percent of global GDP in other SDG investment. The investment increase gradually declines over time.

Online Annex Figure 2.1.2. Comparison of Baseline at the Global Level with GIMF Simulations

(Percent; GDP is in average annual deviation from the path without a public investment increase.)

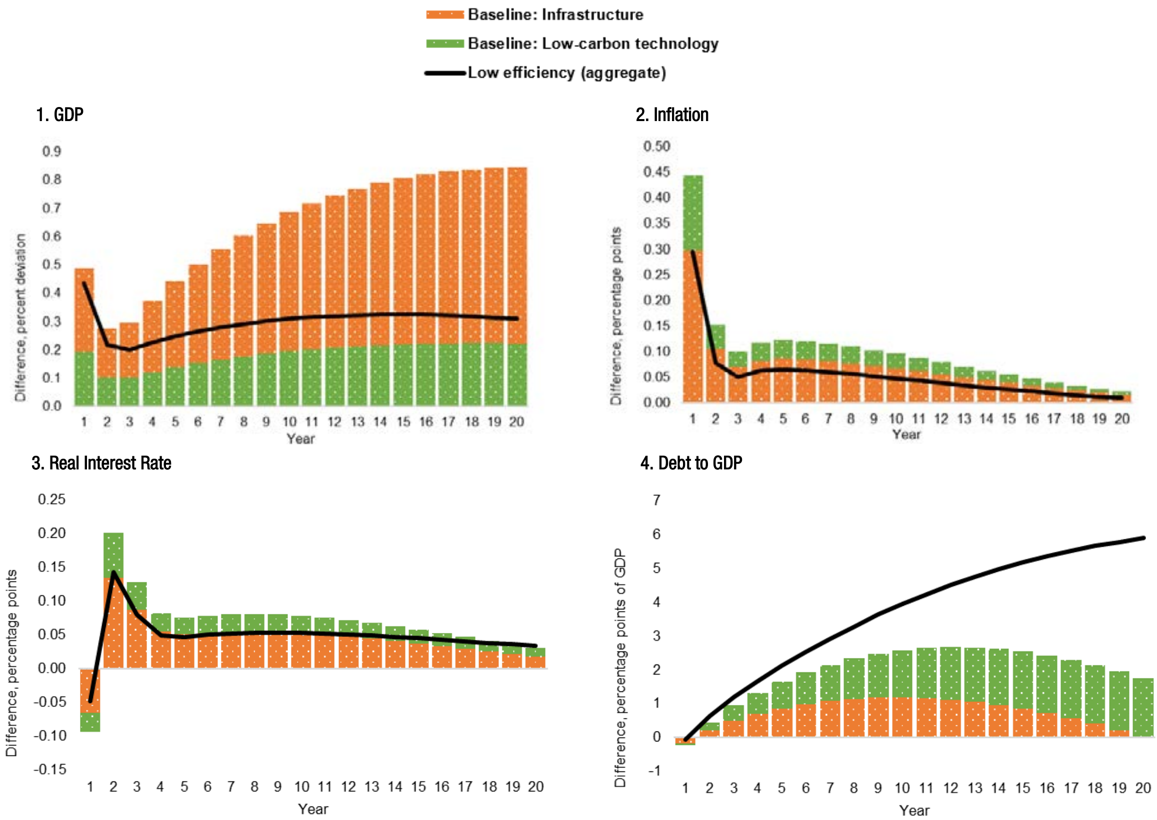
Simulation results are similar to the IMF GIMF model.



Source: IMF staff estimates based on the GIMF model and a revised model of Traum and Yang (2015).

Note: Responses are aggregated across the three types of investment. GIMF = Global Integrated Monetary and Fiscal model; SDGs = Sustainable Development Goals.

Online Annex Figure 2.1.3. Simulated Macroeconomic Effects of a European Union Public Investment Increase
(Difference in percent or percentage points relative to no public investment increase)



Source: IMF staff estimates based on a revised version of Traum and Yang (2015).
Note: Impulse responses to a persistent increase in two types of public investment: The initial increase is 0.35 percent of the euro-area GDP in infrastructure and 0.25 percent of the euro-area GDP in low-carbon technologies. The investment increase gradually declines over time. SDGs = Sustainable Development Goals.

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