GOVERNMENT INVESTMENT AND FISCAL STIMULUS IN THE SHORT AND LONG RUNS

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Abstract. This paper contributes to the debate about fiscal multipliers by studying the impacts of government investment in conventional dynamic stochastic general equilibrium models. The analysis considers two factors that are crucial to understanding the effect of government investment: implementation delays for building public capital projects and future fiscal adjustments to debt-financed spending. The paper demonstrates that implementation delays can produce small or even negative labor and output responses in the short run, while financing instruments and the productivity of public capital matter both quantitatively and qualitatively for long-run growth effects. These results are examined in several models with features relevant for studying government spending, including utility-yielding government consumption, time-to-build for private investment, and government production.
1. Introduction

The recession that began in December 2007 will be the longest and the deepest economic downturn since the Great Depression. The Congressional Budget Office has projected that the economic contraction will last through most of 2009, with only a slow recovery beginning in 2010 [Congressional Budget Office (2009b)]. To prevent further deterioration and facilitate the recovery, the U.S. Congress passed the $787 billion American Recovery and Reinvestment Act, in addition to the $125 billion provided by the Economic Stimulus Act of 2008. This unprecedentedly large scale of discretionary countercyclical fiscal actions has certainly stimulated interest in and debate about the effects of fiscal policy.¹

In addition to its large scale, this fiscal stimulus differs from those of the recent past by relying more on spending increases and less on tax cuts. Nearly two-thirds of the stimulus package is direct government spending and transfers. That spending includes $44 billion for infrastructure expenditures on water quality, transportation, and housing, and another $88 billion in direct federal spending on energy, innovative technology, and federal buildings. [Congressional Budget Office (2009a)]. These infrastructure provisions, which are unusual for countercyclical fiscal packages in the past 30 years, have revived the role of government investment as a countercyclical tool.

This paper contributes to the policy debate by conducting a positive analysis of government investment in dynamic stochastic general equilibrium (DSGE) models. The analysis focuses on two dimensions important for assessing the effects of government investment. We find that the timing of implementation and the methods of fiscal financing are critical to evaluate the effects of government investment. With respect to the former, government investment is often subject to several delays. In addition to the delay in recognizing a need to act, government investment, especially infrastructure projects, are subject to substantial implementation delays. Projects often require coordination among federal, state, and local governments and they have to go through a long process of planning, bidding, contracting, construction, and evaluation. These delays can make the economic benefits from government investment difficult to synchronize with the business cycle.

With respect to fiscal financing, how deficit spending will be financed has important implications for the effects of government investment at longer horizons. This issue is particularly important for the current fiscal situation. A quickly deteriorating federal government budget situation coupled with projections of exploding government debt due to rising health care costs and American demographic shifts [Congressional Budget Office (2007)], suggest that

future policies must adjust to maintain budget solvency.\footnote{The ratio of federal debt held by the public to GDP rose from 0.33 in 2001 to 0.38 in 2008 [table B78 of Economic Report of the President (2009)]. In baseline projections by the Congressional Budget Office (2009b), this ratio increases to 0.56 in 2019.} Distortions from higher income tax rates or lower government spending can undermine the policy objective of promoting growth through productive government investment.

We examine these two issues in DSGE models calibrated to U.S. data. We model the delays between authorization of a government spending plan and completion of an investment project with a time-to-build technology for public capital projects, as in Kydland and Prescott (1982), and investigate the implications of various periods of time-to-build. An enacted spending bill specifies a schedule by which the spending will occur. Delays in implementing government investment imply that consumers and firms learn about spending plans before they are carried out. When private agents act on the expectation of higher infrastructure spending, the economy can be affected even before the public capital projects are completed.\footnote{This phenomenon is the public investment analog to tax foresight studied by Yang (2005) and Leeper, Walker, and Yang (2008) and war spending foresight examined by Ramey (2008).}

So long as public capital is productive, the expectation of higher infrastructure spending generates a positive wealth effect, which discourages work and encourages consumption. Because private investment projects typically do not entail the substantial delays associated with public projects, it takes less time to build private capital. Private investment and employment, therefore, may be delayed until the public capital is on line and raises the productivity of private inputs. Compared to the case without delays, in the short run private investment falls and labor impacts may be small or even negative. Output can fall in the short run in response to an increase in government investment. This result is analogous to the phased-in tax cuts enacted in 2001 and 2003, where expectations of future tax cuts may have induced workers and firms to delay work and production, retarding the recovery from the 2001 recession [House and Shapiro (2006)].

To examine the second issue—the consequences of alternative methods of financing the government spending—we consider various fiscal instruments for future policy adjustments, including reductions in transfers or government consumption, or increases in capital or labor income taxes to stabilize the government debt-to-output ratio. Accounting for future fiscal adjustments is essential to evaluate the impact of government investment over longer horizons. Under lump-sum financing, public capital raises productivity of private production inputs, productive government investment should promote economic growth. This result, however, overlooks the possible contractionary effects introduced by distorting fiscal adjustments to stabilize rising government debt. We find that when public capital is not sufficiently productive, government investment can be contractionary in the long run as the disincentive to invest and work from fiscal adjustments can dominate the higher productivity of private inputs from expansion of public capital.\footnote{Barro (1990), Lau (1995), and Glomm and Ravikumar (1999) examine government spending impacts when distorting taxes are used to finance it, whereas Finn (1993), Ambler and Paquet (1996) assume lump-sum taxes do the financing. Kamps (2004) considers both distorting and non-distorting financing.}

Our aim is to employ widely used models to analyze these two factors in order to better connect our findings to existing literature. Although widely used, the models cannot adequately capture many of the aspects of the U.S. economy that are important for making predictions about the consequences of the American Recovery and Reinvestment Act or other...
policy actions designed to lift the economy out of the 2007-2009 recession. Because the Act includes substantial authorizations for infrastructure spending, this analysis can nevertheless highlight factors associated with expansions in government investment that are important for understanding the impacts of government investment in the short run and the long run.

2. The Model

We analyze the effects of government investment and fiscal financing using several variants of the neoclassical growth model described in this section. The model incorporates several real rigidities often seen in the class of DSGE policy models estimated with data, including habit formation in consumption, investment adjustment costs, and variable utilization rates for private capital [Smets and Wouters (2003, 2007), Bouakez and Rebei (2007), and Leeper, Plante, and Traum (2009)]. We show how our results are robust to different modeling assumptions of the government sector. Across these models, government investment takes the form of productive public capital and is subject to a substantial time-to-build lag. Also, increases in government investment are debt-financed that engender future fiscal adjustments necessary to stabilize the debt-output ratio.

2.1. The Private Sector. The model economy consists of a representative agent, a representative firm, and a government. The agent derives utility from consumption \( C_t \) and leisure \( (1 - L_t) \). The utility function takes the form

\[
U_t \equiv \frac{1}{1 - e} \left( \frac{C_t}{C_{t-1}^b} \right)^{1-e} + \chi \frac{(1 - L_t)^{1-\theta} - 1}{1 - \theta},
\]

where \( e \) and \( \theta \) are the inverses of elasticities of intertemporal substitution of consumption and leisure \( (e > 0 \text{ and } \theta \geq 0) \), and \( \chi \) is the utility weight on leisure. Utility depends on current and last-period consumption; \( b \) indicates the degree of internal habit formation.\(^5\)

The infinitely lived agent maximizes expected lifetime utility

\[
E_t \sum_{t=0}^{\infty} \beta^t U_t(C_t, C_{t-1}, L_t),
\]

subject to the budget constraint

\[
C_t + I_t + B_t + \psi(u_t)K_{t-1} = (1 - \tau^K_t) r_t u_t K_{t-1} + (1 - \tau^L_t) w_t L_t + R_{t-1} B_{t-1} + T_t,
\]

and the law of motion for private capital

\[
K_t = (1 - \delta) K_{t-1} + \Omega(I_t, I_{t-1}).
\]

\( B_t \) is government debt issued at \( t \), which pays \( R_t B_t \) at \( t+1 \). We introduce a capital utilization rate \( u_t \) as in Smets and Wouters (2003) and Christiano, Eichenbaum, and Evans (2005). The steady state capital utilization rate is assumed to be \( u = 1 \) and \( \psi(1) = 0 \). Deviations from the steady state utilization rate incurs a cost, \( \psi(u_t)K_{t-1} \), where \( \psi(u_t) \) is an increasing, convex

\(^5\)The literature has yet to form a consensus about the most appropriate way to model habit formation. Some assume internal habits [McCallum and Nelson (1999), Amato and Laubach (2004), Christiano, Eichenbaum, and Evans (2005), and Kano and Nason (2008)], while others model habits as external [Abel (1990), Smets and Wouters (2003), Ravn, Schmitt-Grohe, and Uribe (2006)]. However, Dennis (2008) shows that to first-order approximation, the difference between internal and external habits is inconsequential for matching business cycle data.
function.\footnote{A more natural way to model the cost of increasing capital utilization is to make the depreciation rate depend on the utilization rate \cite{Burnside}. The current way of modeling has an advantage to identify the capital utilization parameter in estimation \cite{Schmitt}.} \( u_t K_{t-1} \) represents the effective units of private capital. The rental rate for one effective unit of private capital is \( r_t \), and the wage rate is \( w_t \). \( \tau^K_t \) and \( \tau^L_t \) are proportional tax rates levied on capital and labor income. \( T_t \) is lump-sum transfers. Following \cite{Burnside}, we assume investment is subject to an adjustment cost and net investment is given by \[ \Omega(I_t, I_{t-1}) \equiv \left[ 1 - \Gamma \left( \frac{I_t}{I_{t-1}} \right) \right] I_t, \] where \( \Gamma(1) = \Gamma'(1) = 0 \) and \( \Gamma''(1) \equiv \gamma > 0 \). \( I_t \) is interpreted as private gross investment, and in the steady state, \( I_t = I_{t-1} \) and \( \Gamma(1) = 0 \) so gross investment equals net investment. \( \delta \) is the depreciation rate of private capital.

We adopt the standard assumption that time-to-build for private capital is one quarter; that is, \( I_t \) adds to the capital stock \( K_t \), which is productive at time \( t + 1 \). The sensitivity analysis of section 4 relaxes this assumption and allows for longer time-to-build constraints on private capital.

The economy produces goods according to a Cobb-Douglas technology

\[
Y_t = A \left( w_t K_{t-1} \right)^{\alpha_K} \left( L_t \right)^{\alpha_L} \left( K_{t-1}^G \right)^{\alpha_G},
\]

where \( K_{t-1}^G \) is public capital in place at the end of \( t - 1 \). \( \alpha_G \) is the elasticity of output with respect to public capital. When \( \alpha_G = 0 \), government investment is unproductive.

The representative firm, taking prices as given, rents private capital and labor at the rates of \( r_t \) and \( w_t \) to maximize per-period profit

\[
Y_t - r_t u_t K_{t-1} - w_t L_t.
\]

2.2. Government. The government sector purchases consumption goods \( (G_t^C) \) and investment goods \( (G_t^I) \). Revenue is generated through income taxes and by issuing one-period debt to finance its expenditures, which include government purchases, principal and interest service for debt, and transfers to households. The flow government budget constraint is

\[
\tau^K_t r_t u_t K_{t-1} + \tau^L_t w_t L_t + B_t = G_t^C + G_t^I + R_{t-1} B_{t-1} + T_t.
\]

The aggregate resource constraint is

\[
C_t + I_t + \psi(u_t) K_{t-1} + G_t^C + G_t^I = A \left( w_t K_{t-1} \right)^{\alpha_K} \left( L_t \right)^{\alpha_L} \left( K_{t-1}^G \right)^{\alpha_G}.
\]

2.2.1. Modeling the spending process. We model implementation delays in government investment with a time-to-build specification for public capital. We assume public capital does not become productive for several quarters and that government investment in public capital occurs gradually over time.

The motivation for this specification comes from table 1, which reflects the Congressional Budget Office’s cost estimates and outlays for the American Recovery and Reinvestment Act (ARRA) of 2009 and the National Highway Bridge Reconstruction and Inspection Act (NHBRIA) of 2008.\footnote{The NHBRIA bill was not enacted.} The CBO’s cost estimates for the ARRA allow for substantial implementation delays in government investment and show that the outlays occur several years after the authorization. Congress authorized $27.5 billion for highway construction in 2009, yet the estimated outlays are only $2.75 billion for 2009, with a majority of the outlays occurring several years after the authorization. In contrast, the NHBRIA bill was not enacted.

Table 1 suggests that the amount of government investment authorized can deviate substantially from the outlay. To capture this, we assume the government investment implemented (or outlaid) at time $t$ is given by

$$G^t = \sum_{n=0}^{N-1} \phi_n A^t_{t-n},$$

(11)

where $\sum_{n=0}^{N-1} \phi_n = 1$. The $\phi$’s capture the outlay rates of the authorized budget. When $N = 1$, the model does not separate budget authority and outlays, and there is no delay in implementing government investment: $\phi_0 = 1$, and $G^t = A^t$.

We assume agents observe the current and past realizations of the innovations $\{\varepsilon_{t-j}\}_{j=0}^{\infty}$, which implies agents and firms have foresight about government investment as in Ramey.

\[8\] This bill includes many transportation projects. The implementation period of eight years does not imply that all projects take eight years to complete, as some projects do not start until later years.
Minimally, this suggests that agents are aware of budget authorizations, and CBO estimates concerning outlays and expected completion dates—information that is publicly available and widely reported in the press.

Foresight with respect to government investment, coupled with long implementation delays, leads to expectational effects that can mitigate the short-run stimulative nature of government investment. As an example, imagine that in period $t$ the government authorizes construction of a highway that takes 8 quarters to complete ($N = 8$). During the construction period the highway is not useable, so it does not add to the stock of public capital until it is completed at time $t + 7$. Assuming public capital is productive, the knowledge of a future increase in productivity in private inputs will delay private investment and employment. This mechanism runs counter to the aim of expanding government investment to stimulate the economy in the near term.

2.2.2. Debt Financing. Increases in government investment that are initially debt-financed must eventually bring forth adjustments to fiscal policy that ensure solvency. We adopt fiscal rules that adjust transfers, government consumption, or one of the income tax rates to return the debt-output ratio to its steady state level.

$$s_t^T = c^T + \rho^T s_{t-1}^T + q_t^T s_{t-8}^B, \quad q_t^T \leq 0,$$

$$\tau_t^L = c^L + \rho^L \tau_{t-1}^L + q_t^L s_{t-8}^B, \quad q_t^L \geq 0,$$

$$\tau_t^K = c^K + \rho^K \tau_{t-1}^K + q_t^K s_{t-8}^B, \quad q_t^K \geq 0,$$

and

$$G_t^C = c_C + \rho^C G_{t-1}^C + q_t^C s_{t-8}^B, \quad q_t^C \leq 0,$$

where $s_t^T$ is the transfer-output ratio and $s_t^B$ is the government debt-output ratio.\(^9\)

Fiscal adjustments are not triggered until eight quarters after the initial increase in government debt, and the adjustment magnitudes, the $q_t$’s, are time-varying.\(^11\) Two motivations underlie these specifications. First, since the federal government is not subject to year-by-year balanced budget rules, financing rules with delayed fiscal adjustments seem more relevant.\(^12\) Second, it is reasonable to assume that the strength of the fiscal response depends on the level of debt. A higher debt-output ratio invokes a stronger adjustment. To capture this idea, we assume each fiscal adjustment parameter is an increasing function of $s_{t-1}^B$:

$$q_t^i = d^i \log s_{t-1}^B, \quad i \in \{T, L, K, C\},$$

where $d^i = \frac{\log s_t^B}{q_t^i}, s^B$ is the steady state debt-output ratio, and the $q^i$’s are parameters.

\(^9\)It is straightforward to show that this information structure leads to the empirical difficulties described in Ramey (2008) and Leeper, Walker, and Yang (2008).

\(^10\)Take the example of (12). The constant is set to $c^T = s^T - \rho^T s^T - q_t^T s^B$, so that in log-linearized form, (12) becomes $s_t^T = \rho^T s_{t-1}^T + \frac{q_t^T}{s_t^T} q_t^T + \frac{q_t^T}{s_t^T} s_{t-1}^B$. Variables without a time-subscript indicate their steady state values.

\(^11\)Leeper and Yang (2008) adopt similar rules, but assume that the fiscal adjustment parameters, $q$’s, are constant and the adjustment occurs with only a one-quarter lag.

\(^12\)Under current PAYGO rules, new mandatory spending or tax policy changes should not add to the deficit; hence fiscal adjustments should occur within a specified budget window. In recent years, however, PAYGO rules have been waived several times.
2.3. **Calibration.** The model is calibrated at a quarterly frequency. Most parameters are set to values that are typical in real business cycle studies of fiscal policy. Table 2 summarizes the parameter values under the benchmark calibration. In steady state the consumption-output ratio is 0.64, the private investment-output ratio is 0.16, and the share of time devoted to work is 0.2. We justify some of the non-standard parameter values below.

2.3.1. **Public and private capital.** We calibrate the ratio of public to private capital at $K^G/K = 0.32$ in the steady state, which equals the historical U.S. average from 1947-2007 (table 1.1 of Fixed Assets Accounts, BEA). We calibrate the government investment share of output to $s^{GI} = 0.04$, which equals the historical average from 1947 to 2007 (NIPA Table 3.9.5). Given $s^{GI}$ and the ratio of public to private capital, the implied depreciation rate for public capital is $\delta_G = 0.02$, which is comparable to the literature [Baxter and King (1993) and Kamps (2004)] set $\delta = \delta_G = 0.025$.\(^{13}\)

To calibrate the production function (5), we follow Baxter and King (1993) and Glomm and Ravikumar (1997) and assume constant returns to scale with respect to private production factors; $\alpha_K + \alpha_L = 1$.

The literature reflects diverse views about the productivity of public capital ($\alpha_G$). Early work estimates log-linear production functions and tends to find a relatively large $\alpha_G$. Aschauer (1989b) obtains the elasticity of output to nonmilitary public capital to be 0.39, and Aschauer (1989a) finds that the elasticity for core infrastructure (transportation, utility, and water) is 0.24.\(^{14}\) Results from subsequent studies using alternative methodologies are inconclusive about the productivity of public capital. Holtz-Eakin (1994), using state-level data, finds that public-sector capital has no effect on private sector productivity. Evans and Karras (1994), using panel data for 48 states from 1970 to 1986, find that government capital often has statistically significant negative productivity. Kamps (2004) estimates structural VARs to find that an exogenous increase in public capital has no significant effects on output for the U.S. In contrast to these negative results, Nadiri and Mamuneas (1994) obtain significant productive effects from infrastructure and R&D capital in terms of the cost structure and productivity performance of 12 two-digit U.S. manufacturing industries. Pereira and de Frutos (1999) estimate the elasticity of private output with respect to public capital to be between 0.34 and 0.39 for U.S. data from 1956 to 1989.

Given the wide range of estimates for $\alpha_G$, we explore $\alpha_G = 0.05$ (the benchmark value used in Baxter and King (1993)) and $\alpha_G = 0.1$. Under our benchmark calibration $\alpha_K = 0.36$ and $K^G/K = 0.32$, $\alpha_G > 0.12$ implies that the marginal product of public capital is greater than the marginal product of private capital in the steady state. We set the upper bound for $\alpha_G$ to be 0.1.

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\(^{13}\)Based on the data from the current-cost depreciation in the Fixed Assets Accounts (table 1.3), the average annual depreciation rate for government capital is about 0.04. However, using this depreciation rate will imply too little government investment in the steady state. The data also imply a smaller depreciation rate for public capital than for the private capital. Note that capital in our model implicitly includes durable goods, which have higher depreciation rates.

\(^{14}\)The production function approach has been challenged on several econometric grounds, in particular, for missing values and causality problems. See Munnell (1992) and Gramlich (1994) for a survey and the criticisms. Recent work by Kamps (2004) estimates VARs for 22 OECD countries and finds evidence that GDP Granger causes public capital, suggesting reverse causation as assumed when estimating a log-linear production function.
2.3.2. Fiscal variables. The government consumption share of output in the steady state is set to its historical averages, \( s^{GC} = 0.16 \) (1947-2007, NIPA table 3.9.5). Steady-state tax rates on capital and labor income are set to the average tax rates from 1947 to 2007 as constructed by Jones’s (2002) method. We select the transfer-output ratio \( s^T = 0.07 \) so that the debt-output ratio is \( s^B = 0.475 \) in the steady state.\(^{15}\)

In terms of implementation delays, the Congressional Budget Office (2008, p. 19) reports that “for major infrastructure projects supported by the federal government, such as a highway construction and activities of the Army Corps of Engineers, initial outlays usually total less than 25 percent of the funding provided in a given year. For large projects, the initial rate of spending can be significantly lower than 25 percent.” We assume the maximum period to complete a government investment project is three years or \( N = 12 \) in equation (11). The spending rates in table 2, the \( \phi \)'s, are when \( N = 12 \). During the initial quarter when a bill is enacted, we assume zero outlay because of the administrative and planning process involved in an investment project. With three-year time-to-build, at the end of first year 25 percent of the authorized budget is spent (\( \phi_0 = 0 \) and \( \phi_1 = \phi_2 = \phi_3 = 0.083 \); by the end of the second year, two thirds of the authorized budget is spent; the rest is spent during the third year. The analysis also explores another spending pattern, which takes one year to complete: \( N = 4 \), \( \phi_0 = 0 \), and \( \phi_1 = \ldots = \phi_4 = 1/3 \).

To isolate the effect of each fiscal adjustment method, we allow only one fiscal instrument to adjust at a time. The choices of steady-state fiscal adjustment parameters, \( q \)'s in table 2, yield a pattern of debt responses to a government investment shock that roughly follows the paths estimated from U.S. data. Leeper, Plante, and Traum (2009) find that in response to a government spending shock, debt rises with a hump shape and peaks within the first 10 years. Debt still has not returned to its steady state level for 40 to 75 years after the initial increase of government spending, depending on the financing method. Our calibration has the debt-output ratio peak five years after the shock, and it takes about 50 years to return to the steady state level for all financing methods.\(^{16}\) In addition, the path of the debt-output ratio is extremely close across the four financing methods. By controlling this path, we can attribute the differences in responses to financing methods, not to the levels of debt-output ratios along a transition path.

2.3.3. Friction parameters. Finally, we calibrate parameters governing habit formation, investment adjustment costs, and the capital utilization rate adopting values estimated from DSGE models. Bouakez and Rebei (2007) estimate a model with a similar functional form for the habit stock, obtaining the degree of habit formation \( b = 0.25 \). The cost parameter for investment adjustments is set to \( \gamma = 2 \), consistent with Christiano, Eichenbaum, and Evans (2005). The cost parameter for increasing capital utilization rate is set to \( \psi''(1) / \psi'(1) = 0.18 \), as estimated by Smets and Wouters (2003).

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\(^{15}\)The average ratio of federal debt held by the private sector to GDP is 0.42 from 1947 to 2007 [table B79, Economic Report of the President (2009)].

\(^{16}\)The funding horizon may seem quite long. Using U.S. data from 1947 to 2006, Chung and Leeper (2007) estimate that fiscal policy shocks elicit persistent responses in fiscal adjustments and present-value balance for a government spending shock can take 100 years.
3. Impacts of Government Investment

Proponents for increasing government investment or government spending often argue that productive government investment can boost employment in the short run and promote economic growth in the long run.\footnote{Aschauer’s (1989b) work provides empirical links between productive public capital and private productivity. Aschauer (1990) emphasizes the growth effect of government investment, arguing that non-military investment spending is expansionary. Recent policy discussions focus on the ability of government investment to create jobs in the short run [Federal Highway Administration (2002) and Romer and Bernstein (2009)].} Such an outcome is supported by conventional neoclassical growth models with productive public capital, which predict that an unexpected, permanent increase in government investment can generate higher employment, private investment, and output at both short and longer horizons [Baxter and King (1993)]. These positive results hinge, however, on assumptions about the time-to-build public capital and fiscal financing that are embedded in the analysis. We begin with a simplified version of the model in section 2 that better illustrates these points. Then we examine how implementation delays and fiscal adjustments can alter the effects of government investment using the model in section 2.

3.1. Government Investment in a Simple Neoclassical Growth Model. Assuming no rigidities ($b = \gamma = 0$) and no variable capital utilization, log preferences ($e = \theta = 1$), government balances its budget each period by lump-sum taxes, and public capital is subject to one quarter to build, as is private capital, the model in section 2 is then simplified to those of Baxter and King (1993) and Kamps (2004). Figure 1 plots the impulse responses to a permanent increase in government investment under three assumptions about public capital productivity: dotted lines assume $\alpha^G = 0.1$, solid lines assume $\alpha^G = 0.05$, and dotted-dashed lines assume $\alpha^G = 0$.

The model captures three important channels that determine the impacts of government investment: the crowding-out effect, wealth effects (both negative and positive), and the effect from changing the marginal product of private inputs. \textit{Ceteris paribus}, higher government investment reallocates existing resources so there are fewer goods available for the private sector to consume and save. This crowding-out effect is induced by more competition for goods from higher government demand. As goods today become more valuable, the real interest rate rises to clear the goods market. Higher government investment financed by

<table>
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<td>$s^{GI}$</td>
<td>.04</td>
<td>$u$</td>
<td>1</td>
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<td>.16</td>
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<td>$\rho_I, \rho_T, \rho_C, \rho_K, \rho_L$</td>
<td>.9</td>
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Table 2. Benchmark calibration. The spending rates $\phi$’s are the values for three-year delay in implementing government investment ($N = 12$).
lump-sum taxes generates a negative wealth effect, encouraging agents to work harder and save more by reducing consumption. When government investment is productive, however, there is another wealth effect in the opposite direction: a higher stock of productive public capital acts like a total factor productivity increase to create the expectation that more goods will be available in the future. This discourages current saving. Finally, the last effect occurs at longer horizons as public capital gradually builds up, which increases the marginal product of capital and labor. This provides incentives to work and save due to the higher wage rate and return to capital.

Figure 1 shows the impacts of a permanent increase in government investment under three different assumptions about the productivity of government capital. Consumption, private investment, and output responses are in goods units and have the interpretation of multipliers associated with a permanent increase in government investment of one unit.

As shown in the figure, a permanent increase in unproductive government investment (dotted-dashed lines), produces a dominant negative wealth effect. Agents reduce consumption, increase saving (investment), and work more. Consequently, government spending

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The literature studying the effects of unproductive government spending often combines the crowding-out effect with the negative wealth effect, both reducing consumption and increasing labor. But the two effects have different implications for private investment. The crowding out effect indicates that investment would fall, and the negative wealth effect creates an incentive to increase investment (saving).
stimulates output but lowers both consumption and leisure.\textsuperscript{19} However, if government investment is productive, private investment can drop substantially in the short run due to the positive wealth effect from anticipating enhanced future productivity created by a higher stock of public capital. With productive government investment, consumption can be permanently higher while labor is also higher because higher public capital raises the marginal product of labor. Comparing responses under $\alpha^G = 0.1$ and 0.05, we find that the more productive is government investment, the stronger is the positive wealth effect, and the greater is the initial decline in private investment.

A transitory ($\rho_I = 0.9$) government spending shock elicits somewhat different responses. Figure 2 plots the impulse responses under the same three values of $\alpha^G$. While output remains positive, unlike permanent government investment increases, private investment falls initially, regardless of the value of $\alpha^G$. When a government investment shock is transitory, the two opposite wealth effects from higher taxes and higher future income become weaker. In the short run, the crowding-out effect dominates, lowering both consumption and saving. As the productive public capital stock gradually accumulates, private investment eventually rises in response to the resulting increase in productivity of private capital.

It may seem surprising that enhanced productiveness of public capital generates larger initial declines in private investment. Private investment falls by 0.6 units when $\alpha^G = 0.1$ and by 0.4 units when $\alpha^G = 0.05$. This difference arises because the larger $\alpha_G$ produces a stronger positive wealth effect, which raises the consumption profile at the expense of saving.

This simple model predicts immediate and sustained increases in labor and output whether government spending is productive or unproductive. The channels through which labor and output increase, however, are quite different: with unproductive government spending the main channel is a negative wealth effect, while for productive government investment the primary channel is the resulting increase in the productivity of private inputs. In either case, the results provide some support for the use of government spending or government investment to expand employment and output. Now we turn to how these results change in our main model, which accounts for implementation delays in government investment and allows for distorting fiscal financing.

3.2. Implementation Delays: Time-to-Build Public Capital. We return to the model in section 2. Because permanent increases in government investment are rare, the analysis focuses on transitory increases. To illustrate the impacts of implementation delays on short-term responses, we assume lump-sum financing; the choice of fiscal adjustment has little influence in the short run.

Figure 3 plots responses to an exogenous government investment shock for $\alpha^G = 0.1$ and 0.05. The figure reports results for three different periods between when the budget for an investment project is authorized and when the project is completed: one quarter ($N = 1$, dashed lines); one year ($N = 4$, dotted-dashed lines); three years ($N = 12$, solid lines). Implementation periods up to a year apply to maintenance projects for existing infrastructure or new smaller projects, while a three-year delay applies to large infrastructure projects, such as a dam or a new interstate highway. To facilitate comparison, we scale the responses such that the area under the three curves of government investment equals one unit of good.

\textsuperscript{19}This is often referred to as the “neoclassical view” of government spending, as examined by Barro (1989). Gali, Lopez-Salido, and Valles (2007) and Monacelli and Perotti (2008) argue that the crowding out of private consumption is inconsistent with vector autoregressive evidence and propose creative modeling techniques to reconcile theory with the VAR evidence.
Implementation delays alter the short-run dynamics substantially, especially for consumption, labor, and output. Under the usual assumption of no delays (or one quarter to build), the responses are similar to those in the simple model [figure 2]: consumption and private investment fall but output and labor rise immediately. Investment adjustment costs generate a hump-shaped decline in investment because adjustment costs punish rapid changes. Private investment does not rise until more than three years after the shock.

When there are implementation delays, private investment does not rise until much later: after more than four years with one-year delay and seven years with three-year delay. The peak decline is also larger than in the case without delays. Implementation delays imply a slower build-up of public capital, and, therefore, a slower increase in the marginal product of private inputs. Because it takes less time to build private capital, agents postpone investment until the public capital stock is built up.

While investment responses differ only quantitatively when there are implementation delays, consumption, labor, and output differ qualitatively in their short-run dynamics. As in the simple model, the driving force for an immediate increase in labor without delay is the crowding-out effect or negative wealth effect. Under implementation delays, the government absorbs a fewer goods initially and the crowding out effect is smaller in the short run. On the other hand, since the total increase in government investment is the same across the
three delay periods, the positive wealth effect from higher future public capital operates in each case. Less crowding out, coupled with the same positive wealth effect, generates a slight decline in employment and a slight increase in consumption in the short run, in contrast to the case without delays.

With implementation delays, labor also declines in the short run because the marginal product of labor rises only gradually as public capital gets installed. With longer implementation delays, the rebound in investment and labor is also slower. Consequently, with a three-year delay, output does not begin to rise until almost two years after the shock; with a one-year delay, output does not rise until two quarters after the shock.

When $\alpha^G = 0.05$, the qualitative patterns of all variables follow closely to those with $\alpha^G = 0.1$ [second column of figure 3]. Under $\alpha^G = 0.05$, the initial decline in labor and output under delayed implementation is, however, negligible. As public capital is less productive, the positive wealth effect induced from more productive public capital is also smaller. When $\alpha^G = 0.05$ and $N = 4$ or $N = 12$, this positive wealth effect is almost canceled out entirely by the crowding-out effect, leaving little impact on consumption, labor, and output for the initial two to three quarters. Since public capital is less productive, the subsequent increase of private investment and labor is also smaller because the productivity of private inputs rises more modestly.
Although various spending rates have little influence on the responses at longer horizons, the above analysis shows that an implementation delay is qualitatively and quantitatively important for short-run dynamics. Contrary to the results when there is no implementation delay—that an increase in government investment is expansionary and raises employment immediately—we find that implementation delays imply that productive government investment can have little effect or even a negative effect on labor and output in the short run. This period can be as brief as a couple of quarters or as long as a couple of years. In addition, the short-run decline in private investment can be larger and longer compared to the case without implementation delays. Implementation delays are an important factor to evaluate the short-term effects of government investment.

3.3. Fiscal Adjustments. Another important consideration for determining the effects of government investment, particularly in the long run, are the ultimate sources of fiscal financing. Up to this point, we exploited the Ricardian equivalence of the models when government spending is financed by non-distorting taxes. Of course, stimulus packages like the American Recovery and Reinvestment Act finance higher government spending by selling government debt. We examine four alternative schemes for financing and eventually retiring the expansion in new debt: adjustments to future lump-sum taxes, unproductive government spending, capital taxes, and labor taxes. Fiscal adjustment parameters follow the values in table 2. Figure 4 plots responses when $\alpha_G = 0.1$ for each of the four financing schemes. As the figure makes evident, the choice of financing instrument matters a great deal for the effects in the long run.

Fiscal adjustments through distorting financing methods create another channel that influences the impacts of government investment. Raising income tax rates or reducing government consumption offsets some of the growth effects from higher productive public capital. The net effect over longer horizons can be expansionary or contractionary. Among the four methods of financing, regardless of the length of implementation delays, government investment is most expansionary when non-distorting transfers are reduced, and it is least expansionary—in fact, contractionary—when government raises the tax rate on capital income. As shown in the path of private investment (the third column), raising the marginal tax rate on capital income generates strong negative impacts on private investment. These negative effects can dominate the positive impacts from more productive public capital. Lower private investment also reduces the marginal product of labor, driving down employment. Combining these two factors, output falls below its initial level five to seven years after the initial government investment shock and stays persistently low before returning to the steady state.

Increasing the tax rate on labor income to stabilize debt reduces the after-tax return on labor, which drives down labor inputs and output relative to the case with transfer reductions. A reduction in (unproductive) government consumption, lowers the amount of resource government absorbs from the economy and offsets some of the crowding out effects from the increase in government investment. As a result, labor falls more and consumption rises relative to the case with transfer reductions. Lower labor in turn reduces some of the growth effect from the productive government investment.\(^{21}\)

\(^{20}\)We also examine the responses under $\alpha_G = 0.05$. The response patterns are very close to figure 4, and hence not shown here.

\(^{21}\)Section 4 explores the case where government consumption generates utility.
The less productive is government investment (smaller $\alpha^G$), the more likely government investment is to be contractionary in the long run. While not shown here, in the extreme case $\alpha^G = 0$, output turns significantly negative for all three distorting financing methods and is expansionary only when transfers adjust.


In this section, we check the robustness of our conclusions along three dimensions. Our analysis so far has assumed that government consumption is unproductive. Following the literature in studying the relationship between government consumption and private consumption, we allow government consumption to be a complement or a substitute with private consumption. Second, we have assumed time-to-build for government investment based on an institutional argument, but not for private capital. Since the time-to-build assumption is initiated to model the construction process for capital in general, we explore the case where private capital is subject to one year to build. Finally, we model the government sector separately from the private sector, allowing it to employ labor and capital to produce government output.

4.1. Utility from Government Government Consumption. Following Bouakez and Rebei (2007), the agent derives utility from leisure $(1 - L_t)$ and effective consumption $(\bar{C}_t)$, which is assumed to be a constant-elasticity-of-substitution index of private consumption $(C_t)$ and government consumption $(G^C_t)$, as given by

$$\bar{C}_t = \left[ \phi C_t^{\frac{\nu-1}{\nu}} + (1 - \phi) \left( G^C_t \right)^{\frac{\nu-1}{\nu}} \right]^{\frac{1}{\nu}}, \text{ with } 0 \leq \phi \leq 1, \nu > 0.$$  

(17)

When $\phi = 1$, effective consumption collapses to $C_t$, and we are back to the model in section 2. $\nu$ is the elasticity of substitution between private and government consumption: $\nu = 0$ indicates private and government consumptions are perfect complements; $\nu \to \infty$ implies that the two are perfect substitutes. Preferences take the form

$$U_t \equiv \frac{c_t}{1 - e} \left( \frac{\bar{C}_t}{C_t^{\theta-1}} \right)^{1-e} + \chi \frac{\left(1 - L_t\right)^{1-\theta} - 1}{1 - \theta}.$$  

(18)

We set the weight on private consumption to be $\phi = 0.8$ as in Bouakez and Rebei (2007). They estimate a DSGE model with the utility function in (18) using U.S. data, and find that the elasticity of substitution between private and government consumption is $\nu = 0.33$. When $e = 2$, as in our benchmark calibration, $\nu < \frac{1}{2}$, which implies Edgeworth complementarity between private and government consumption.

Figure 5 plots impulse responses for $\nu = 0.33$ and $\alpha^G = 0.1$. Comparing figure 5 with figure 4, where the only difference is $\phi = 0$ (agents place no weight on government consumption), responses of private consumption, investment, output, and labor to a government investment shock are very similar under adjustments in transfers and the two income tax rates. When the fiscal adjustment reduces government consumption, private consumption rise in most periods, in contrast to the case with unproductive government consumption. Output also falls over longer horizons, as does employment for most periods.

When government and private consumption are complements, a decrease in government consumption reduces the marginal utility derived from private consumption, reducing the incentive to consume. In the previous case when $\phi = 0$, a reduction in government consumption offsets the crowding-out effect from higher government investment, which drives
up private consumption. In the current case ($\phi = 0.8$ and $v = 0.33$), private consumption co-moves with government consumption. A decrease in private consumption demand makes labor fall and output falls in the out years despite higher private investment.

Given the uncertainty about the relationship between private and government consumption in the literature, we also investigate the case where government and private consumption are Edgeworth substitutes by setting $v = 0.6$. The responses for all variables under the four methods of fiscal adjustments are very close to those in figure 4 and hence are not shown here. If government consumption is a substitute for private consumption, reductions in government consumption (to reduce deficits) make private consumption rise, reinforcing the crowding-out effect in the case of unproductive government consumption.

Some authors justify treating government and private consumption as complements because it generates positive co-movement in government and private consumption [Bouakez and Rebei (2007)], as in the VAR evidence [Blanchard and Perotti (2002) and Gali, Lopez-Salido, and Valles (2007)]. Although the literature has not settled on theoretical grounds to explain why private consumption rises following a government spending increase, our conclusion that government investment impacts depend on implementation delays and fiscal adjustments hold, whether government consumption is unproductive, a complement, or a substitute with private consumption.

4.2. Time-To-Build for Private Capital. Kydland and Prescott (1982) incorporate time-to-build for construction of all new productive capital to explain the autocovariances of real output and the covariances of cyclical output with other macro variables. To this point, we have assumed time-to-build for public capital but not for private capital. This raises a concern that our results of little or negative output and labor responses to a government investment shock initially may be due to the asymmetric treatment of time-to-build. In this subsection, we extend our main model to allow one year to build for private capital as assumed in Kydland and Prescott (1982) and McGrattan (1994).

Let $S_t$ be in the investment project started at $t$, which takes four quarters to construct and form private capital. The law of motion for private capital is

$$K_t = (1 - \delta) K_{t-1} + S_t. \tag{19}$$

At time $t$, the fraction of investment project $S_t$ implemented is $\phi_0^S$, and $\phi_1^S$, $\phi_2^S$, and $\phi_3^S$ are the fractions implemented at $t + 1$, $t + 2$, and $t + 3$. At any given time, the implemented investment is

$$\sum_{t=0}^{3} \phi_i^S S_{t-i} = \Omega (I_t, I_{t-1}), \quad \sum_{t=0}^{3} \phi_i^S = 1,$$

where $\Omega (I_t, I_{t-1})$ is net investment excluding adjustment costs and the gross investment cost is $I_t$. The rest of the model economy is the same as the setup in section 2.

To calibrate the time-to-build parameters, we turn to empirical estimates for these parameters. Kydland and Prescott (1982) assume all tangible capital has an average construction period of one year with equal rates for each quarter, but empirical findings reject this assumption. McGrattan (1994) fits a DSGE model with U.S. data from 1947 to 1987 and estimates $\phi_0^S = 0.475$, $\phi_1^S = 0.0433$, $\phi_2^S = 0.0683$, and $\phi_3^S = 0.4134$. These parameters are estimated

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A common specification assumes government and private consumption are additive in a utility function. Estimations under this specification is also inconclusive about whether government consumption and private consumption are Edgeworth substitutes or complements [Kormendi (1983), Aschauer (1985), Ahmed (1986), Karras (1994), and Ni (1995)].
with high precision, but the M-shaped patterns are counterintuitive. Normally, we expect decaying completing rates over time. Montgomery (1995) estimates the value-weighted average completion pattern for U.S. nonresidential structures (1961-1991) and finds a high initial completion rate followed by a slow decaying pattern, with the average construction period of 16.7 months. Figure 6 contains impulse responses with $\phi_0^S$’s set to the values McGrattan estimates. We also compute impulse responses using the alternative pattern $\phi_0^S = 0.45$, $\phi_1^S = 0.30$, $\phi_2^S = 0.15$, and $\phi_3^S = 0.1$. The results are very close to figure 6, and are not shown here.

This model is identical to the main model when $\phi_0^S = 1$ and $\phi_1^S = \phi_2^S = \phi_3^S = 0$. The most noticeable difference between figures 6 and 4 is investment responses. When there is no time-to-build for private capital, investment falls much more in the short run and rises before returning to steady state. With the assumption of one year to build, the decline in the private investment in the short run is much smaller and it never rises. In the earlier explanation, private investment rises in later years mainly because of rising marginal product of capital due to more productive public capital. While this incentive still exists with time-to-build for private capital, private investment now represents the moving average of investment initiated each period. The decision to reduce investment in the initial five to ten years is spread over a longer period of time so that the later incentive to invest more is offset by earlier declines.

Overall, our earlier finding that the implementation delays in government investment can prolong and deepen the negative private investment responses still holds under time-to-build for private capital. In addition, we still find labor and output have almost no short-run responses when there are implementation delays in government investment, while they rise immediately when there are no implementation delays. At longer horizons, as in figure 4, government investment contracts output when capital taxes are raised to stabilize debt.

4.3. A Two-Sector Model with Government Production. Actual governments employ workers and purchase intermediate goods and services to produce government consumption and investment, which perform various public services (national defense, public order and safety, transportation, education, etc.). Like firms, government also rents labor from private agents. The macroeconomic literature generally does not model government as a separate production sector. To examine more closely the employment impacts of an increase in government investment, we change the model specification in section 2, so that government combines intermediate goods and labor to produce government output similar to Cavallo (2005).\textsuperscript{23} We broadly define labor devoted to government production ($L_t^G$) to include jobs paid for with government resources. For example, if a government agency contracts an infrastructure project to a private construction firm, the jobs generated by this project are labeled as $L_t^G$ in the model.\textsuperscript{24}

The output of the economy ($Y_t$) is the sum of private output ($Y_t^P$) and government output ($Y_t^G$)

$$Y_t = Y_t^P + Y_t^G.$$  \hspace{1cm} (20)

Private output is produced by a Cobb-Douglas technology

$$Y_t^P = A^P K_{t-1}^{\alpha_K} (L_t^P)^{\alpha_L} (K_{t-1}^G)^{\alpha_G},$$

\textsuperscript{23}Cavallo (2005) does not distinguish government purchases between government consumption and investment.

\textsuperscript{24}In the accounting by the Bureau of Labor Statistics, government employment refers to those directly employed by government agencies.
where $A^P$ is the total factor productivity for the private technology and $L^P_t$ is labor employed by the private sector. Since private production is assumed to be perfectly competitive, the zero profit condition implies

$$Y^P_t = r_t u_t K_{t-1} + w_t L^P_t. \quad (21)$$

Government hires workers and purchases intermediate goods and services ($\tilde{G}_t$) to produce output with a Cobb-Douglas technology

$$Y^G_t = A^G \left( L^G_t \right)^{\alpha_L} \left( \tilde{G}_t \right)^{1-\alpha_L},$$

where $A^G$ is the total factor productivity for the government production. The government sector produces government consumption ($G^C_t$) and government investment ($G^I_t$), which accumulates into public capital in the future for private production. The net contribution of government production to the final output in the economy is then

$$Y^G_t = G^C_t + G^I_t - \tilde{G}_t. \quad (22)$$

In the model without government production, the cost of government spending is the expenditure on government consumption and investment. With government production, the cost is the expenditure on intermediate goods and the wage bill. The government’s budget constraint becomes

$$\tau^L w_t L_t + \tau^K r_t u_t K_{t-1} - T_t + B_t - R_{t-1} B_{t-1} = G_t + w_t L^G_t. \quad (23)$$

In the National Income and Product Accounts (Table 3.10.5), the main cost of producing government consumption is compensation to government employees and purchases of intermediate goods and services.\(^{25}\) In our model, we assume government pays the prevailing wage in the private sector, $w_t$, which equals the marginal productivity of labor for private production,

$$w_t = \alpha_L \frac{Y^P_t}{L^P_t}, \quad (24)$$

so government’s wage cost is $w_t L^G_t$.

The rental rate for private capital, $r_t$, becomes

$$r_t = \alpha_K \frac{Y^P_t}{K_{t-1}}. \quad (25)$$

Labor can move costlessly between the two production sectors and aggregate labor is the sum of labor inputs in the two sectors,

$$L_t = L^P_t + L^G_t. \quad (26)$$

The aggregate resource constraint is

$$C_t + I_t + \psi(u_t) K_{t-1} + G^C_t + G^I_t = Y_t. \quad (27)$$

The model introduces a new fiscal variable $\tilde{G}_t$. We assume that

$$\tilde{G}_t = z \left( G^C_t + G^I_t \right), \quad 0 < z < 1. \quad (28)$$

\(^{25}\)The cost also includes depreciation of government fixed capital, which is a proxy for capital cost. This is a small part (less than one tenth) of the government consumption expenditures. Since we do not assume government uses public capital to produce its output, we ignore this cost here.

\(^{26}\)Appendix A contains the derivation of this constraint, and shows the accounting consistency for the income and product sides in this model.
This means government increases the purchase of intermediate goods and services proportionally to the gross government output. The rest of the setup for preferences and government fiscal policy are the same as in section 2.

To calibrate this economy, we assume that in steady state, \( \frac{L_G}{L} = 0.2 \), which is identical to the government consumption and investment share of total output (\( \frac{G^C + G^I}{Y} \)). The value of \( z \) in (28) is set to the ratio of the sum of intermediate goods and services purchased and government investment to the sum of government consumption and investment for 2007 (line 6 of NIPA Table 3.10.5, and lines 1 and 3 of NIPA Table 3.9.5); this gives \( z = 0.55 \). The transfer-output ratio is reset to 0.0574 so that the steady state debt-output ratio is the same as the one implied under the earlier benchmark calibration, 0.47. The fiscal adjustment parameters are also modified to yield a valid solution: \( q_T = -0.0006 \), \( q_L = 0.001 \), \( q_K = 0.005 \), and \( q_C = -0.007 \).

Figures 7 and 8 plot the impulse responses to an exogenous government investment shock under \( \alpha^G = 0.1 \) and \( \alpha^G = 0.05 \). Again, solid lines assume it takes three years to build public capital, dotted-dashed lines assume one year, and dashed lines assume one quarter.

A model with government production explicitly captures the rising competition for goods and labor due to an increase in government spending. In a model without government production, the increase in aggregate labor is due to the crowding-out effect or negative wealth effect. The private sector feels poorer and reduces consumption. This drives up the value of work. Labor supply increases, raising aggregate employment and reducing the wage rate.

The prediction that higher government spending lowers wages is at variance with empirical evidence that finds the opposite [Rotemberg and Woodford (1992), Fatas and Mihov (2001), and Gali, Lopez-Salido, and Valles (2007)]. The addition of government production, however, predicts a rising wage rate following an increase in government spending. Government draws additional labor for its production when it increases government spending. The higher government demand for labor raise aggregate employment and the wage rate, in contrast to models without government production.

In response to a rising wage rate, private labor falls, driving down the marginal product of private capital. As shown in figure 7, output falls across all financing methods and under various periods of time to build for public capital. The initial fall in output is the smallest when government investment is subject to longest time to build (solid lines). Because the initial spending rates are small when time-to-build is long, the labor drawn by government production is also small and wage increase modest.

Compared to earlier results without government production (figure 4, \( \alpha^G = 0.1 \)), private investment also falls more in the case of government production. In addition to the crowding-out effect and wealth effect, when government draws labor to produce, the falling marginal product of private capital due to smaller private labor inputs amplifies the original reduction

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\(^{27}\)Seitz (1994) investigates the impact of provision of public capital on demand for private inputs using German data. He finds a negative relationship between public capital and demand for private labor.

\(^{28}\)Studies using the narrative approach based on war dummies, however, find that an increase in war spending leads to a lower wage rate [see Edelberg, Eichenbaum, and Fisher (1999) and Ramey and Shapiro (1998)].

\(^{29}\)Finn (1998) finds that to a positive government employment shock, output, consumption, private investment, and private labor fall, but average labor productivity rises. This is consistent with these findings. In her model, government is not modeled as a separate production sector, and government spending is not linked with government labor as in our setup.
in private investment. With a larger decline in output, consumption also falls more relative to the case without government production.

In later years, one noticeable difference from the model without government production is the case when the capital tax rate is raised to stabilize debt. Without government production, output falls substantially in later years, but stays positive with government production under $\alpha^G = 0.1$. In general, when the capital tax rate is increased, it depresses investment, and lowers the marginal product of labor. This shifts the labor demand curve to the left and lowers the wage rate. Agents move down the labor supply curve. The equilibrium wage rate and aggregate labor both fall. Since private investment also falls, output decreases. With government production, higher government investment increases labor demand, which offsets the decline in private labor demand. If public capital is sufficiently productive, as in the case of $\alpha^G = 0.1$, the wage rate in later years does not fall, and the aggregate labor does not decline, as it does in the case without government production. Consequently, output does not fall as it does in the case without government production. On the other hand, when public capital is less productive as $\alpha^G = 0.05$ in figure 8, output can decline in later years.

In this model with government production, we explicitly model the channel that government spending “creates” jobs. The results however show that more jobs generated by government spending does not necessarily translate into higher output. In contrast, the increased labor demand drives up the wage rate, which reinforces the contractionary effects in the short run.

Some economists would argue that in a recession there are idle labor resources, so government production does not raise wages and crowd out private employment. Our model, and most macro models, cannot address this point. Since government investment is likely to be subject to substantial implementation delays, it is quite possible that some of the government investment will occur when the economy is already on its way to recovery. In that circumstance, competition from production factors from increasing government spending can lead to the economic effects as captured in the model with government production.

5. Government Investment Multipliers

Government spending multipliers are often used to summarize the stimulative effects of fiscal policy. We compute the cumulative multipliers over forty years for output, consumption, and private investment for a one dollar increase in government investment. In reality, government does not rely on a single financing method for fiscal adjustments. To compute multipliers, we consider two classes of fiscal adjustments: all fiscal instruments, distorting and non-distorting, adjust or only lump-sum taxes adjust. When all the instruments adjust, the weight on each instrument is calibrated to those estimated from data. Leeper, Plante, and Traum (2009) use Bayesian methods to estimate federal fiscal multipliers in U.S. data from 1960-2008. They find that data prefer a model that allows all financing methods—government spending, transfer, and capital and labor income taxes—to respond to debt. Their estimation shows that government relied more on adjusting transfers and capital income taxes to stabilize debt and less on government spending and labor income taxes. The weights are 0.44, 0.33, 0.19, and 0.04 for transfers, capital taxes, government consumption, and labor taxes, respectively.\footnote{Fiscal rules estimated in Leeper, Plante, and Traum (2009) are slightly different from those used here. They assume that government responds to deviations in the level of debt, not the debt-output ratio and the response lag is only one quarter.}
Table 3. Cumulative output multipliers to a total increase in government investment of $1. M1 is the main model (section 2). M2 is the model where government consumption is a complement to private consumption (section 4.1). M3 is the model with time-to-build for private capital (section 4.2). M4 is the model with government production (section 4.3). Multipliers computed assuming all government fiscal instruments adjust to stabilize debt. Numbers in parentheses are multipliers when only lump-sum taxes adjust to stabilize debt.

<table>
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<th>M1</th>
<th>M2</th>
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<tr>
<td>$\alpha^G = 0.1$</td>
<td></td>
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<tr>
<td>1 Q delay</td>
<td>2.56 (4.11)</td>
<td>1.31 (3.28)</td>
<td>2.18 (3.65)</td>
<td>2.32 (2.57)</td>
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<tr>
<td>1 Y delay</td>
<td>2.53 (4.05)</td>
<td>1.35 (3.25)</td>
<td>2.25 (3.63)</td>
<td>2.46 (2.51)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>2.29 (3.96)</td>
<td>1.29 (3.21)</td>
<td>2.18 (3.60)</td>
<td>2.18 (2.46)</td>
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<tr>
<td>$\alpha^G = 0.05$</td>
<td></td>
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<tr>
<td>1 Q delay</td>
<td>−0.10 (2.42)</td>
<td>−0.63 (2.09)</td>
<td>0.15 (2.24)</td>
<td>−0.58 (1.07)</td>
</tr>
<tr>
<td>1 Y delay</td>
<td>−0.04 (2.39)</td>
<td>−0.53 (2.07)</td>
<td>0.24 (2.23)</td>
<td>−0.34 (1.02)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>−0.11 (2.35)</td>
<td>−0.55 (2.05)</td>
<td>0.25 (2.22)</td>
<td>−0.42 (0.46)</td>
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Table 4. Cumulative consumption multipliers to a total increase in government investment of $1. M1 is the main model (section 2). M2 is the model where government consumption is a complement to private consumption (section 4.1). M3 is the model with time-to-build for private capital (section 4.2). M4 is the model with government production (section 4.3). Multipliers computed assuming all government fiscal instruments adjust to stabilize debt. Numbers in parentheses are multipliers when only lump-sum taxes adjust to stabilize debt.

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<tr>
<td>$\alpha^G = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Q delay</td>
<td>1.68 (2.36)</td>
<td>0.85 (1.66)</td>
<td>1.40 (1.96)</td>
<td>0.88 (1.07)</td>
</tr>
<tr>
<td>1 Y delay</td>
<td>1.60 (2.26)</td>
<td>0.80 (1.59)</td>
<td>1.41 (1.94)</td>
<td>0.80 (0.90)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>1.39 (2.10)</td>
<td>0.64 (1.47)</td>
<td>1.37 (1.91)</td>
<td>0.56 (0.77)</td>
</tr>
<tr>
<td>$\alpha^G = 0.05$</td>
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<td></td>
</tr>
<tr>
<td>1 Q delay</td>
<td>−0.07 (0.95)</td>
<td>−0.43 (0.66)</td>
<td>0.02 (0.82)</td>
<td>−0.98 (−0.29)</td>
</tr>
<tr>
<td>1 Y delay</td>
<td>−0.08 (0.89)</td>
<td>−0.42 (0.62)</td>
<td>0.06 (0.81)</td>
<td>−0.99 (−0.41)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>−0.16 (0.82)</td>
<td>−0.47 (0.56)</td>
<td>0.05 (0.80)</td>
<td>−1.06 (−0.46)</td>
</tr>
</tbody>
</table>

Tables 3, 4, and 5 present the multipliers for both the distorting and the non-distorting financing schemes and across four model specifications. The models are: M1 (model in section 2); M2 (government consumption and private consumption are complements—section 4.1); M3 (time-to-build for private capital—section 4.2); M4 (government production—section 4.3).

Productivity of public capital, $\alpha^G$, is the dominant factor determining the size of government investment multipliers. Since implementation delays mainly affect short-run dynamics, they have small effects on cumulative multipliers. When $\alpha^G = 0.1$, output, consumption, and
investment multipliers are larger than those under $\alpha^G = 0.05$ across the four specifications of the models (the main model in section 2 and three alternative specifications in section 4). Since implementation delays mainly affect short-run dynamics, it has very small influence on the overall effects of government investment.

Multipliers are uniformly larger—often much larger—when government investment is financed by lump-sum taxes. Output multipliers over two are commonplace, even when government capital is relatively unproductive ($\alpha^G = 0.05$) and they can be over four when government capital is more productive ($\alpha^G = 0.1$). Nonetheless, the range of output multipliers is quite large: they can even be negative when $\alpha^G = 0.05$ and government hires labor and intermediate goods to produce its spending goods.

When distorting fiscal instruments finance government investment, the output multipliers range from $-0.57$ to 2.63. When $\alpha^G = 0.1$, all the multipliers are bigger than 1. When $\alpha^G = 0.05$, the only model that delivers a positive multiplier is when there is time-to-build for private capital, mainly because total private investment falls less.

The consumption multipliers range from $-1.05$ to 1.68 with distorting financing and from $-0.46$ to 2.36 with lump-sum taxation. While all consumption multipliers with distorting financing are negative when $\alpha^G = 0.05$, the majority are only slightly negative (below $-0.5$), with the exception of the case where government consumption is a complement to private consumption. Since government consumption in later years is reduced to stabilize debt, the complementarity reinforces the negative private consumption responses.

Finally, the investment multipliers range from $-1.30$ to 1.24 across models and financing schemes. Despite the small effect of implementation delays on cumulative multipliers, there is some influence on private investment responses: the longer the delay in government investment, the smaller the investment multipliers within a model for a given $\alpha^G$.

The results presented here suggest a wide range of multipliers for government investment. These multipliers are computed under the assumption of all financing methods are used to stabilize government debt or only lump-sum taxes are used. If government relies more on

<table>
<thead>
<tr>
<th>$\alpha^G$</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha^G = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Q delay</td>
<td>0.60 (1.24)</td>
<td>0.46 (1.21)</td>
<td>-0.12 (-0.10)</td>
<td>-0.22 (-0.08)</td>
</tr>
<tr>
<td>1 Y delay</td>
<td>0.43 (1.04)</td>
<td>0.27 (0.99)</td>
<td>-0.13 (-0.11)</td>
<td>-0.45 (-0.37)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>0.08 (0.75)</td>
<td>-0.10 (0.65)</td>
<td>-0.14 (-0.13)</td>
<td>-0.77 (-0.62)</td>
</tr>
<tr>
<td>$\alpha^G = 0.05$</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Q delay</td>
<td>-0.51 (0.44)</td>
<td>-0.58 (0.40)</td>
<td>-0.07 (-0.06)</td>
<td>-1.06 (-0.56)</td>
</tr>
<tr>
<td>1 Y delay</td>
<td>-0.58 (0.32)</td>
<td>-0.69 (0.27)</td>
<td>-0.08 (-0.06)</td>
<td>-1.19 (-0.78)</td>
</tr>
<tr>
<td>3 Y delay</td>
<td>-0.71 (0.19)</td>
<td>-0.79 (0.13)</td>
<td>-0.08 (-0.06)</td>
<td>-1.29 (-0.87)</td>
</tr>
</tbody>
</table>

Table 5. Cumulative investment multipliers to a total increase in government investment of $\$1$. M1 is the main model (section 2). M2 is the model where government consumption is a complement to private consumption (section 4.1). M3 is the model with time-to-build for private capital (section 4.2). M4 is the model with government production (section 4.3). Multipliers computed assuming all government fiscal instruments adjust to stabilize debt. Numbers in parentheses are multipliers when only lump-sum taxes adjust to stabilize debt.
raising capital taxes, multipliers can become much more negative for all three variables. On the other extreme, if government relies more on cutting lump-sum transfers or raising labor income taxes, multipliers can be larger. Finally, given the large difference in the output multipliers between $\alpha^G = 0.1$ and $\alpha^G = 0.05$, the importance of productivity of government capital for fiscal stimulus is apparent.

6. Concluding Remarks

This paper studies the macroeconomic effects of government investment in the short run and long run. We show that a substantial time-to-build lag in a standard neoclassical model can make expansions in government investment contractionary in the short run, at worst, and have a muted impact, at best. This result is robust across different assumptions on fiscal adjustments, productivity of public capital, the role of government consumption, and time-to-build for private capital. It is also robust to assuming that the government is a production sector, where government investment directly generates jobs. Over longer horizons, we show that the choice of fiscal adjustment instruments is important for minimizing the negative effects from stabilizing government debt. The productivity of government investment is also critical. The more productive public capital, the less likely that government investment is contractionary in the long run.

The neoclassical framework we employ is completely standard in macroeconomic research. Nonetheless, it has its limitations, particularly in addressing the circumstances surrounding the recession of 2007-2009. For all its simplicity, the model does highlight two important mechanisms at work in the current environment: large government infrastructure projects take time to build and, therefore, can have rather different impacts in the short run than in the long run; how government investment ultimately gets financed matters a great deal for the long-run consequences of any fiscal package with a substantial infrastructure component. Both mechanisms are integral to making accurate predictions of the effects of fiscal expansions from government investment.
Rewrite the government flow budget constraint of (23) as
\[ T_t = r_t^L w_t L_t + \tau_t^K r_t u_t K_{t-1} + B_t - R_{t-1} B_{t-1} - \tilde{G}_t - w_t L_t^G. \]  
Combining (29) with the agent’s budget constraint (3), and then applying the aggregate labor constraint (26) to get
\[ C_t + I_t + \psi(u_t) K_{t-1} + \tilde{G}_t = r_t u_t K_{t-1} + w_t L_t^P. \]  
Using the equilibrium condition (21) for private prediction in (30), we obtain an expression for private output,
\[ Y_t^P = C_t + I_t + \psi(u_t) K_{t-1} + \tilde{G}_t. \]  
Next, combine private output (31) with the expression for government output (22), we have
\[ Y_t^P + Y_t^G = C_t + I_t + \psi(u_t) K_{t-1} + G_t^C + G_t^I = Y_t, \]  
which is equivalent to equation (8). Since the product side and income side of an economy must coincide, the model implies the resource value of government output equals the cost to produce them. In other words,
\[ G_t^C + G_t^I = \tilde{G}_t + w_t L_t^G. \]  
To check aggregate income of the economy, combine (21), (22), (33), and (26) to obtain
\[ Y_t^P + Y_t^G = r_t u_t K_{t-1} + w_t L_t^P + G_t^C + G_t^I - \tilde{G}_t \]
\[ = r_t u_t K_{t-1} + w_t L_t^P + G_t L_t^G \]
\[ = r_t u_t K_{t-1} + w_t L_t. \]
References


Figure 4. Impulse responses to a shock of government investment under the benchmark calibration: $\alpha^G = 0.1$. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. All responses are in goods units except labor, which is in percent deviations from its steady state level. The area under $G^I = 1$ for all scenarios.
Figure 5. Impulse responses to a shock of government investment with government consumption as a complement to private consumption: $\alpha^G = 0.1$. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. All responses are in goods units except labor, which is in percent deviations from its steady state level. The area under $G^I = 1$ for all scenarios.
Figure 6. Impulse responses to a shock of government investment with time-to-build for private capital, $\alpha^G = 0.1$. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. All responses are in goods units, and the area under $G^I = 1$ for all delays and for all fiscal adjustments.
Figure 7. Impulse responses to a shock of government investment with government production $\alpha^G = 0.1$. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. All responses are in goods units except labor, which is in percent deviations from its steady state level. The area under $G^I = 1$ for all scenarios.
Figure 8. Impulse responses to a shock of government investment with government production $\alpha^G = 0.05$. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. All responses are in goods units except labor, which is in percent deviations from its steady state level. The area under $G^I = 1$ for all scenarios.