Government Investment and Fiscal Stimulus in the Short and Long Runs*

Eric M. Leeper, Todd B. Walker, and Shu-Chun S. Yang

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Abstract

This paper contributes to the policy debate about fiscal stimulus by studying government investment in an estimated neoclassical growth model. The analysis focuses on two dimensions that are critical for understanding the effects of government investment: implementation delays for building public capital and expected fiscal adjustments to deficit-financed spending. Implementation delays can produce small or even negative labor and output responses to increases in government investment in the short run. Anticipated fiscal adjustments matter both quantitatively and qualitatively for long-run growth effects. When public capital is insufficiently productive, distorting financing can make government investment contractionary at longer horizons.

Keywords: Government Investment; Implementation Delays; Fiscal Stimulus; Time-To-Build; Effects of Fiscal Policy; DSGE Bayesian Estimation

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*We thank Bob King, Christopher Sleet, and an anonymous referee for helpful comments. Leeper: Department of Economics, Indiana University and NBER, eleeper@indiana.edu; Walker: Department of Economics, Indiana University, walkertb@indiana.edu; Yang: Congressional Budget Office, susan.yang@cbo.gov. The views expressed in this paper are those of the authors and should not be interpreted as those of the Congressional Budget Office.

1 Introduction

The recession that began in December 2007 is the longest and the deepest economic downturn since the Great Depression. In response to the recession, the U.S. Congress passed several fiscal stimulus bills, including the $787 billion American Recovery and Reinvestment Act (ARRA) of 2009.[1] In addition to the large scale, the ARRA differs from those in the recent past by relying more on spending increases and less on tax cuts. Nearly two thirds of the stimulus package is government spending and transfers. That spending includes $44 billion for infrastructure expenditures on water quality, transportation, and housing, and another $88 billion in 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.[2]

Government investment seems ideal for counteracting recessions. In the short run, government investment can offset falling private demand by increasing purchases of goods and services. In the longer run, government investment may become productive public capital, promoting economic growth. This perspective, though, overlooks two issues that are critical to how government investment affects the economy: implementation delays and future fiscal financing adjustments.

This paper contributes to the on-going policy debate by conducting a positive analysis of government investment in an estimated neoclassical growth model fit to U.S. postwar data. The analysis shows that implementation delays and expected fiscal adjustments can hinder the beneficial effects of government investment at both short and long horizons. Implementation delays determine the rate of spending outlays for government investment, and the speed at which spending occurs is crucial for short-run stimulative effects. Many projects, especially infrastructure, require coordination among federal, state, and local governments and have to go through a long process of planning, bidding, contracting, construction, and evaluation. To model these delays, we use a time-to-build setup to characterize the formation of public capital, as in Kydland and Prescott (1982).

With respect to fiscal adjustments, how deficit spending is ultimately financed matters for the effects of government investment at longer horizons. This issue is especially pertinent to the current fiscal situation. A quickly deteriorating federal government budget situation

[1]ARRA was estimated to add about $720 billion stimulus between fiscal years 2009 and 2011, roughly 5 percent of GDP in 2009. In addition to ARRA, Congress also passed the Economic Stimulus Act of 2008 and the Worker, Homeownership, and Business Assistance Act of 2009, estimated to add about $190 billion stimulus between fiscal years 2008 and 2011.

[2]On March 4, 2010, the House of Representatives also passed H.R. 2847, which authorizes funding for more infrastructure projects, is intended to increase employment.

suggests that future policies *must* change to maintain fiscal sustainability.[3] To model the effects of fiscal adjustments, we allow a variety of fiscal instruments—transfers, government consumption, and income taxes—to adjust with a two-year lag to rising government debt. Debt-financed fiscal expansions then trigger expected adjustments in spending and taxes that ensure policy is sustainable.

Compared to a scenario with little delay, implementation delays for government investment can lead private investment to fall more and labor and output to rise less (or even decline slightly) in the short run. So long as public capital is productive, the expectation of higher government investment spending generates a positive wealth effect, which discourages current work effort. Depending on the implementation speed, this positive wealth effect could dominate the usual negative wealth effects from increasing government purchases, resulting in small or even negative effects on labor and output in the short run. In addition, because private investment projects typically do not entail the substantial delays associated with public projects, private investment does not rebound until later, when the public capital is on line and raises the productivity of private inputs. Implementation delays can postpone the intended economic stimulus and may even worsen the downturn initially by reducing employment and output.

Delays in government investment are 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 postpone work and production, actions that House and Shapiro (2006) argue retarded the recovery from the 2001 recession.[4] Current weakness in employment growth, which falls short of the administration's predictions of the effects of the ARRA, may be partly attributable to implementation delays in government investment.[5] By the end of fiscal year 2009, outlays for infrastructure spending from the ARRA were less than 10 percent of the budget authority granted for infrastructure in that year [Congressional Budget Office (2010b)], despite the claim that many projects were "shovel ready."

Distorting fiscal financing dampens the growth effects of government investment over longer horizons. Estimates find that the government has systematically relied on cutting government consumption and transfers and raising income taxes to stabilize debt in the

[3] The CBO projects that the federal debt-GDP ratio will rise from 41 percent in 2008 to 60 percent in 2010 [Congressional Budget Office (2010a)], while over longer horizons rising health care costs and an aging population conspire to put debt on an explosive trajectory in the absence of any change in current tax and spending laws [Congressional Budget Office (2009b)].

[4] The impact of expectations on future fiscal policy changes, or fiscal foresight, is also studied by Yang (2005) and Leeper, Walker, and Yang (2009a) for taxes and by Ramey (2009) for war spending.

[5] Romer and Bernstein (2009a) projected that the ARRA would lower the unemployment rate by about 1 percentage point by the end of 2009. While the employment path without the ARRA is unobservable, their prediction that the unemployment would be around 7.7 percent in 2010Q1 is more optimistic than the outturn: the unemployment rate stood at 9.7 percent in February 2010.

post-1960 sample. When public capital is only weakly productive, government investment can be contractionary at longer horizons as the disincentives to invest and work due to distortionary fiscal adjustments can dominate the incentives from higher productivity of private inputs. The *speed* of fiscal adjustment is also a significant factor in determining the ability of government investment to offset cyclical movements in macro aggregates: stimulative impacts of deficit-financed increases in government investment are mitigated if distortionary fiscal instruments rapidly retire debt.

The recent debate on fiscal stimulus has inspired a number of authors to study government spending multipliers.[6] Together with earlier estimates [Ramey and Shapiro (1998), Blanchard and Perotti (2002), and Mountford and Uhlig (2009)], economists have offered an embarrassingly wide range of estimated multipliers: from -1 (the present-value multiplier 20 quarters after a spending increase in Mountford and Uhlig (2009)) to 3.7 (the impact multiplier when the zero nominal interest rate bound is binding in Christiano, Eichenbaum, and Rebelo (2009)). Those studies focus on unproductive government spending. Our multiplier calculations highlight two aspects of government spending largely overlooked by the recent literature: whether the spending is productive and delays in when the spending occurs. Even in a standard neoclassical growth model with distorting financing, present-value cumulative multipliers for output can exceed 1 if public capital is sufficiently productive. In contrast to the typical pattern that the multiplier for government spending is largest initially and then declines over time [as in Forni, Monteforte, and Sessa (2009) and Zubairy (2009)], the multiplier for government investment under implementation delays can be much smaller in the short run than in the long run.

2 The Model

We construct a neoclassical model that allows for implementation delays and distorting fiscal adjustments. The model incorporates several real rigidities—habit formation in consumption, investment adjustment costs, and variable capital utilization—often seen in the class of DSGE models fit to data [for example, Smets and Wouters (2003, 2007), Bouakez and Rebei (2007)]. It resembles the model that Leeper, Plante, and Traum (forthcoming) estimate.

[6] For example, see Barro and Redlick (2009), Christiano, Eichenbaum, and Rebelo (2009), Cogan, Cwik, Taylor, and Wieland (2009), Davig and Leeper (2009), Denes and Eggertsson (2009), Eggertsson (2009), Hall (2009), Uhlig (2009).

2.1 Households The representative household derives utility from consumption, c_t, and disutility from labor, l_t, and maximizes

$$E_t \sum_{t=0}^{\infty} \beta^t u_t^b \left[\frac{(c_t - hC_{t-1})^{1-\gamma}}{1-\gamma} - u_t^l \frac{l_t^{1+\kappa}}{1+\kappa} \right], \tag{1}$$

subject to the budget constraint

$$\left(1+\tau_t^C\right) c_t + i_t + b_t = \left(1-\tau_t^K\right) r_t^K v_t k_{t-1} + \left(1-\tau_t^L\right) w_t l_t + r_{t-1} b_{t-1} + z_t, \tag{2}$$

where $\beta \in (0,1)$ is the discount factor and $1/\gamma, 1/\kappa \geq 0$ are the elasticity of intertemporal substitution and the Frisch labor elasticity. The model has two preference shocks: u_t^b affects the household's discount rate and u_t^l is a labor preference shock. Both follow AR(1) processes

$$\ln u_t^j = \rho_j \ln u_{t-1}^j + \sigma^j \varepsilon_t^j, \quad \varepsilon_t^j \sim N(0,1), \ j \in \{b, l\}. \tag{3}$$

We assume external habit formation for consumption: $h \in [0,1]$ is the habit parameter, and C_{t-1} is lagged aggregate consumption. At time t, the household purchases one-period government bonds, b_t, that pay $r_t b_t$ units of goods at $t+1$, with r_t the gross real interest rate. There are three distorting taxes: τ_t^C is the consumption tax rate and τ_t^K and τ_t^L are the tax rates levied on capital and labor income. The intensity at which private capital, k_t, is used can vary, and v_t denotes the utilization rate. r_t^K is the rate of return on capital. Following Christiano, Eichenbaum, and Evans (2005), the law of motion for private capital is

$$k_t = \left[1 - \delta(v_t)\right] k_{t-1} + \left[1 - s\left(\frac{u_t^i i_t}{i_{t-1}}\right)\right] \times i_t, \tag{4}$$

where $s(\cdot)$ is the adjustment cost function for investment. In steady state, $s(1) = s'(1) = 0$, and $s''(1) \equiv s > 0$. Adjustment costs are subject to an investment specific shock u_t^i, obeying the process

$$\ln(u_t^i) = \rho_i \ln(u_{t-1}^i) + \sigma_i \varepsilon_t^i, \quad \varepsilon_t^i \sim N(0,1). \tag{5}$$

The depreciation rate depends on capital utilization intensity, as in Greenwood, Hercowitz, and Huffman (1988). Specifically,

$$\delta(v_t) = \delta_0 + \delta_1 (v_t - 1) + \frac{\delta_2}{2} (v_t - 1)^2, \tag{6}$$

following Schmitt-Grohe and Uribe (2008). In steady state, $v = 1$ so the steady state depreciation rate is δ_0.

2.2 Firms

Perfectly competitive firms produce output y_t according to

$$y_t = u_t^a (v_t k_{t-1})^{\alpha} (l_t)^{1-\alpha} \left(K_{t-1}^G\right)^{\alpha^G}, \tag{7}$$

where K_{t-1}^G is aggregate public capital, and α^G is the elasticity of output with respect to public capital, indicating the productiveness of public capital.[7] u_t^a is total factor productivity and follows the process

$$\ln u_t^a = \rho_a \ln u_{t-1}^a + \sigma_a \varepsilon_t^a, \quad \varepsilon_t^a \sim N(0,1). \tag{8}$$

The firm's optimality conditions imply that in equilibrium

$$r_t^K = \frac{\alpha Y_t}{K_{t-1}}; \quad w_t = \frac{(1-\alpha) Y_t}{L_t}, \tag{9}$$

where capital letters denote aggregate values.

2.3 Government

The government each period decides on a set of fiscal instruments to satisfy its flow budget constraint,

$$\tau_t^C C_t + \tau_t^K r_t^K v_t K_{t-1} + \tau_t^L w_t L_t + B_t = G_t^C + G_t^I + r_{t-1} B_{t-1} + Z_t, \tag{10}$$

where G_t^C is government consumption, G_t^I is *implemented* government investment. Later we introduce *authorized* for government investment, A_t, to be distinguished from G_t^I. In equilibrium, the goods market clearing condition is

$$C_t + I_t + G_t^C + G_t^I = Y_t. \tag{11}$$

2.3.1 Modeling the spending process

We assume that government investment turns into public capital through a time-to-build process. Our modeling approach differs from those in the literature [Baxter and King (1993) and Kamps (2004)], in which policy decisions for government investment are in terms of budget authority, rather than government investment actually implemented. Legislative authorities in the United States and elsewhere enact appropriation bills to provide funding for spending on government investment (and for other non-mandatory spending programs). How much actual spending (outlays) occurs, however, depends on implementation.

To distinguish budget authority from actual spending, let N be the number of quarters

[7] As in Baxter and King (1993) and Glomm and Ravikumar (1997), we assume increasing returns to scale with respect to public capital.

between granting budget authority and completing a project. Then, the law of motion for public capital is

$$K_{t-1}^{G}=(1-\delta_G)\,K_{t-2}^{G}+A_{t-N}. \tag{12}$$

Suppose that the government authorizes funding at time $t-12$ for a highway that takes three years to build ($N=12$). Then the highway would not be used in production until t (as K_{t-1}^{G} is used to produce goods at time t). Also, let the sequence $\{\phi_0,\phi_1,\phi_2,...,\phi_{N-1}\}$ denote the spending rates for an authorized budget. Then government investment implemented (or outlaid) at time t is given by

$$G_t^I=\sum_{n=0}^{N-1}\phi_n A_{t-n}, \tag{13}$$

where $\sum_{n=0}^{N-1}\phi_n=1$. When $N=1$, $\phi_0=1$ and $G_t^I=A_t$, as modeled in the literature. Policy decisions about authorizations of government investment follows the process

$$\ln A_t=\rho_A\ln A_{t-1}+\sigma_A\varepsilon_t^A,\quad \varepsilon_t^A\sim N\left(0,1\right). \tag{14}$$

This specification for government investment is motivated by the fact that in practice the amount of government investment authorized can deviate substantially from outlays. Table 1 contains the Congressional Budget Office's estimates of costs and outlays associated with two pieces of legislation involving government investment. Based on historical spending rates, the CBO assumes that outlays for government investment flow over several years following the authorization. For the ARRA, Congress authorized \$27.5 billion for highway construction in 2009, yet the estimated outlays are only \$2.75 billion for fiscal year 2009, with the bulk of the outlays occurring over the next six years.[8] Nearly half of the estimated outlays occur after fiscal year 2011. Another example is the National Highway Bridge Reconstruction and Inspection Act of 2008, which would have authorized appropriations of about \$1 billion in fiscal year 2009 for repairing, rehabilitating, and replacing bridges on public roadways.[9] Outlays associated with this legislation would have extended more than four years into the future. The estimated first-year outlays account for only 27 percent of the total budget authority, while the cumulative outlays at the end of second year are only about 67 percent.

Short-run impacts of government investment programs hinge critically on distinguishing between authorization and outlays.

[8] The implementation period of eight years does not imply that all projects take eight years, as some projects do not start until later.

[9] The bill was not enacted.

2.3.2 Debt Financing

Increases in deficit-financed government investment must eventually bring forth adjustments to fiscal policy that ensure budget solvency. Leeper, Plante, and Traum (forthcoming) find that the federal government relied on government consumption, transfers, and income taxes to stabilize debt in the post-1960 sample. We adopt similar specifications for fiscal policy. In log-linearized forms (denoted by a hat), the fiscal rules are

$$\hat{Z}_t = -\psi_Z \hat{Y}_t - \gamma_Z \hat{s}^B_{t-8} + u^Z_t, \quad \hat{u}^Z_t = \rho_Z \hat{u}^Z_{t-1} + \sigma_Z \varepsilon^Z_t; \tag{15}$$

$$\hat{\tau}^i_t = \psi_i \hat{Y}_t + \gamma_i \hat{s}^B_{t-8} + u^i_t, \quad \hat{u}^i_t = \rho_i \hat{u}^i_{t-1} + \sigma_i \varepsilon^i_t, \quad i \in \{K, L\} \tag{16}$$

$$\hat{\tau}^C_t = u^C_t, \quad \hat{u}^C_t = \rho_C \hat{u}^C_{t-1} + \sigma_C \varepsilon^C_t; \tag{17}$$

and

$$\hat{G}^C_t = -\gamma_G \hat{s}^B_{t-8} + u^G_t, \quad \hat{u}^G_t = \rho_G \hat{u}^G_{t-1} + \sigma_G \varepsilon^G_t, \tag{18}$$

where $\hat{s}^B_{t-8} \equiv \frac{B_{t-8}}{Y_{t-8}}$ and ε_t's$\sim N(0,1)$.[10] Fiscal adjustments to debt expansions do not occur immediately; the model builds in an 8-quarter lag before fiscal instruments react to increase in the debt-to-output ratio. Because the federal government is not subject to year-to-year balanced budget rules, delayed financing is more relevant empirically than is immediate adjustment. A priori, we expect that the government would cut transfers or government consumption, or increase income taxes to stabilize debt growth, as reflected by positive values for the γ's.[11] We also allow transfers and income tax rates to respond to output fluctuations within the period, capturing automatic stabilizers.

3 Estimation

We estimate the model with U.S. quarterly data from 1960Q1 to 2008Q1 using the Bayesian inference method described in An and Schorfheide (2007). Ten observables are used in the estimation: consumption, investment, hours worked, consumption tax revenue, capital tax revenue, labor tax revenue, government consumption, government investment, government transfers, and debt. Fiscal data include federal and state and local governments. Appendix A describes data details.

Note that the data do not include budget authority for government investment and the

[10]The consumption tax rate is exogenous and may seem redundant in our analysis. Since we use government debt as an observable in the estimation, and debt is constructed through the accumulation of government net borrowing consistent with the NIPA concept (see appendix A), consumption taxes are necessary to equal actual tax receipts.

[11]Our specification does not allow government investment to adjust in response to debt. The estimation by Traum and Yang (2009), using federal data alone, finds that government investment responds to debt are insignificant.

NIPA data on government investment are not informative about the spending rates, ϕ's.[12] Instead of estimating the spending rates, we estimate a version of the model assuming one quarter of delay: $N = 1$, $\phi_0 = 1$, and $G_t^I = A_t$. When conducting analysis, the effects of government investment are examined under different scenarios of the spending rates. Implicitly, we take the stand that structural parameters are invariant to the spending rates for government investment. Given the small share of government investment in output—about 4 percent in the sample—spending rates are unlikely to influence the preference and technology parameters.

Choices of priors largely follow those in Leeper, Plante, and Traum (forthcoming). Sims's (2001) method for solving linear rational expectations and his minimization routine, csminwel, are used. To find the posterior mode we perform searches initiated from 50 different starting points, and the results suggest that multiple modes are not a concern.[13] To simulate the posterior distribution, we use the random walk Metropolis-Hasting algorithm and perform diagnostics to ensure convergence of the MCMC chain.[14] Table 2 contains priors, mean, 5th and 95th percentiles, and standard deviations of the posterior distributions.

Except for the labor tax response to debt, γ_L, the 90-percent posterior intervals for all parameters do not contain zero. For the structural parameters, most of our estimates are comparable to those in Leeper, Plante, and Traum (forthcoming).[15] Our estimate of the capitalization parameter, δ_2, is lower than Leeper, Plante and Traum's 90-percent interval but closer to the estimate obtained by Schmitt-Grohe and Uribe (2008). For debt financing parameters, $(\gamma_{GC}, \gamma_K, \gamma_L, \gamma_Z)$, our priors do not impose that the estimates be positive. Except for the labor tax rate, all fiscal instruments have been used systematically to stabilize debt.

3.1 Calibrated Parameters

In addition to spending rates, there are other parameters that are difficult to identify. We calibrate them to values commonly adopted in the literature. These include the discount factor, $\beta = 0.99$ (implying an annual real interest rate of 4 percent), the capital income share, $\alpha = 0.36$, the steady state depreciation rate of private capital, $\delta_0 = 0.025$, and the ratio of public to private capital $\frac{K^G}{K} = 0.31$ (the historical average from 1960 to 2007, Table 1.1 of Fixed Assets Accounts). We also calibrate steady-state fiscal variables to sample means: $\frac{G^I}{Y} = 0.038$ (where Y is the sum of government consumption

[12] To our knowledge, there are also no readily available data on aggregate budget authority enacted for all levels of governments.

[13] Forty-four searches converge to the same values, and the rest either do not converge or converge to values with much lower likelihood.

[14] We sample one million draws from the posterior distribution and discard the first 50,000 draws. The sample is thinned by every 200 draws to remove serial correlations between draws. We check the trace plots and performing Geweke's (2005) separated partial mean test for convergence diagnostics.

[15] Our estimation differs from Leeper, Plante, and Traum (forthcoming) mainly in that we distinguish between government consumption and investment and use fiscal data for all levels of government.

and investment, private consumption, and investment, consistent with (11)), $\frac{G^C}{Y} = 0.144$, $\tau^K = 0.384$, $\tau^L = 0.214$, $\tau^C = 0.095$, and the ratio of government debt to annual output to 0.381. Given the values of $\frac{G^I}{Y}$ and $\frac{K^G}{K}$, the model implies that $\delta_G = 0.02$.

3.1.1 Productivity of public capital

The parameter α^G is critical to determine the effects of government investment. Unfortunately, the data we have cannot identify it. The literature has diverse views on the productivity of public capital. Early work estimates log-linear production functions and tends to find a large α^G.[16] Results obtained by alternative methodologies, however, are inconclusive. 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, Nadiri and Mamuneas (1994) obtain significant productivity effects from infrastructure and R&D capital in 12 two-digit U.S. manufacturing industries. Given the lack of consensus on the productivity of public capital, we explore relatively small values: $\alpha^G = 0.05$ (the benchmark value used in Baxter and King (1993)) and $\alpha^G = 0.1$.

3.1.2 Spending rates, ϕ's

We examine three scenarios for implementation delays in government investment: $N = 12$ (three-year delay) for large infrastructure projects like a new highway; $N = 4$ (one-year delay) for maintenance or small new projects; and $N = 1$ (one-quarter delay) as typically assumed in the literature. When $N = 12$ or 4, zero outlay is assumed for the initial quarter because of the administrative and planning process. When $N = 12$, by the end of first year 25 percent of the authorized budget is spent ($\phi_0 = 0$ and $\phi_1 = \phi_2 = \phi_3 = \frac{0.25}{3}$), and the remaining authorized budget is spent equally among the remaining eight quarters ($\phi_4 = ... = \phi_{11} = \frac{0.75}{8}$). When $N = 4$, we assume $\phi_0 = 0$ and $\phi_1 = \phi_2 = \phi_3 = \frac{1}{3}$.[17]

[16] Aschauer (1989b) obtains 0.39 for the elasticity of output to non-military public capital, and Aschauer (1989a) finds that the elasticity for core infrastructure is 0.24. These estimates have been challenged for missing variables and endogeneity problems [see Munnell (1992) and Gramlich (1994)]. Kamps (2004) also finds evidence that GDP Granger causes public capital, suggesting reverse causation as assumed in the log-linear production approach.

[17] Our assumptions on the spending rates for large projects are conservative. Congressional Budget Office (2008) states 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" (p. 19).

4 Impacts of Government Investment

Government investment is often argued to boost employment and promote economic growth, making it an ideal candidate to counteract business cycles.[18] The argument is supported by conventional neoclassical growth models with productive public capital [Baxter and King (1993) and Kamps (2004)]. We show that implementation delays and distortionary fiscal financing of debt can alter this sanguine view of the the short-run stimulative effects and long-run growth effects of government investment.

4.1 Implementation Delays

Figure 1 plots responses to an exogenous government investment shock for $\alpha^G = 0.05$ using the mean estimates of the posterior distribution for parameters.[19] Solid lines are responses for a three-year delay ($N = 12$), dotted-dashed lines are those for a one-year delay ($N = 4$), and dashed lines are those for a one-quarter delay ($N = 1$). To facilitate comparison, we scale the responses so that the areas under the three curves of government investment equal one unit of goods (bottom panel). All responses except labor are in goods units; labor is in percentage deviations from steady state.

When government spending is unproductive, as is government consumption in the model, the dominant effect of increasing government spending is a negative wealth effect, which raises labor and decreases consumption—the "neoclassical view" [Barro (1989)]. When government spending is productive, as is government investment when $\alpha^G > 0$, two additional effects follow. First, anticipating a higher stock of public capital generates expectations that more goods will be produced in the future, generating a positive wealth effect. This wealth effect dampens the labor increase from the negative wealth effect in the neoclassical view, and consumption falls less. Second, as public capital gradually builds up, it increases the marginal product of private inputs and eventually induces agents to work and accumulate capital in response to higher expected returns.

As shown in figure 1, implementation delays alter short-run dynamics substantially, especially for consumption, labor, and output. Under the typical assumption of one-quarter delay (dashed lines), the short-run responses are consistent with the neoclassical view: consumption and investment fall but output and labor rise immediately. When implementation delays are longer, however, the immediate jump in output and labor is replaced by slightly negative responses on impact and muted response during initial periods. Under longer implementation delays, the government absorbs fewer goods each period. With less competition for goods from the government, consumption falls less and labor rises less. At the same time,

[18] See Aschauer (1989b, 1990) or more recent policy discussion in Federal Highway Administration (2002) and Romer and Bernstein (2009b).

[19] Impulse responses when $\alpha^G = 0.1$ are very similar to those shown here. Productivity of public capital matters more at longer horizons.

since the total increase in government investment is the same regardless of delay lengths, the positive wealth effect from higher future public capital is identical across the three scenarios. Taken together, these two factors imply that the longer the implementation delays, the smaller the positive responses in output and labor in the short run.

Implementation delays also matter for the response pattern of private investment. Under a three-year delay, it takes two-years longer for investment to turn positive. And the longer the delay, the more negative the investment response in the short run. Longer implementation delays imply a slower build-up of public capital, and therefore, a slower increase in the marginal product of private capital. Because it takes less time to build private capital, agents postpone investment until public capital can significantly raise the productivity of private production inputs.

4.2 Fiscal Adjustments Sources of fiscal financing have important implications for how government investment affects the economy, particularly over longer horizons. Estimates reveal that historically debt has been stabilized by adjustments in distorting fiscal instruments, in particular, government consumption and capital taxes. Because lump-sum financing is frequently assumed in the literature [for example, Finn (1993) and Ambler and Paquet (1996) and part of the analysis in Baxter and King (1993) and Kamps (2004)], we contrast the results under the estimated financing mechanisms to those under lump-sum financing. We also consider the case when only income taxes adjust, as Barro (1990), Lau (1995), and Glomm and Ravikumar (1999) assume. Finally, we investigate how the speed at which debt is paid back affects outcomes.

4.2.1 Financing method Figure 2 plots responses to an increase in government investment for $\alpha^G = 0.05$ (the left column) and $\alpha^G = 0.1$. Because implementation delays have little influence on responses at long horizons, we illustrate the role of fiscal financing only under a three-year delay. The path of government investment is the same as the solid line in figure 1. Solid lines in figure 2 reflect outcomes when all instruments adjust according to the mean estimates of fiscal parameters in table 2. Dotted-dashed lines are the outcomes when only lump-sum transfers adjust ($\gamma_Z = 0.155$ and $\gamma_{GC} = \gamma_K = \gamma_L = 0$). Dashed lines arise when only income taxes adjust ($\gamma_K = 0.143$, $\gamma_L = 0.077$, and $\gamma_{GC} = \gamma_Z = 0$).[20]

The choice of financing instrument matters a great deal for the effects of government investment at longer horizons, regardless of how productive public capital is. Fiscal adjustments involving distortionary financing methods create another channel that influences the effects of government investment. Raising income tax rates or reducing government con-

[20] The mean estimates of γ_K and γ_L are insufficient to stabilize debt growth when other instruments are set to 0. We scale the mean estimates of γ_K and γ_L by 1.5 to ensure an equilibrium exists.

sumption offsets some of the growth effects from more productive public capital. Among the three methods of financing, government investment is most expansionary when non-distorting transfers are reduced (dotted-dashed lines) and is least expansionary—in fact, can be contractionary— when government raises income tax rates.

The dashed lines of the right column in figure 2 show that when public capital is weakly productive (in this case, $\alpha^G = 0.05$), consumption, investment, and output are persistently negative at long horizons when income tax rates alone adjust to stabilize debt. On the other hand, if public capital is more productive (in this case, $\alpha^G = 0.1$), government investment can expand output throughout the horizon (except for an initial negative response due to implementation delays).

Our results show that studies that ignore distorting fiscal financing are likely to overstate the growth effects of deficit-financed government investment. Although cutting lump-sum transfers produces the most growth, it is worth nothing that our analysis overlooks the distributional effects of government investment. As a significant portion of transfers go to households with low-income, debt-financing through transfers reductions can substantially reduce the welfare of some segments of the population.

4.2.2 Financing speed

Figure 3 plots the responses to a government investment shock assuming a three-year implementation delay when $\alpha^G = 0.05$. The solid lines are responses under the mean estimates in table 2, where the government does not begin to retire the debt until two years after the initial increase in debt (as assumed in the earlier analysis). The dotted-dashed lines assume that the response magnitudes to debt (the γ's coefficients) are twice as large, and that the government begins to retire debt only one year after the increase in the debt-to-output ratio.

Speeding up debt retirement brings forward the negative impact of distorting debt financing from raising tax rates or reducing government consumption. Retiring debt more quickly dampens the expansionary effects government investment in the short run. The dotted-dashed lines in figure 3 show that labor and output do not rise as high as under slower debt retirement. In particular, output turns negative (as a result of distorting debt financing) earlier and by a larger magnitude, compared to the estimated speed of debt retirement.

Retiring debt early, of course, leads to smaller accumulation of debt and, therefore, smaller eventual fiscal adjustments. If the policy objective is to stimulate the economy by government investment in the short run, then retiring debt too soon could defeat that purpose. Generally speaking, the financing speed is important not only for the short-run effects of government investment but for the effectiveness of all countercyclical fiscal measures.

5 Present-Value Multipliers

Government spending multipliers are often used to summarize the effects of fiscal policy. Following Mountford and Uhlig (2009), we compute the present-value multipliers for output, consumption, and private investment. Specifically, the present-value multiplier k quarters after an increase in government spending is defined as

$$\frac{\sum_{i=0}^{k}\left(\prod_{j=0}^{i} r_{t+j}^{-1}\right)\triangle Y_{t+i}}{\sum_{i=0}^{k}\left(\prod_{j=0}^{i} r_{t+j}^{-1}\right)\triangle G_{t+i}^{I}}, \tag{19}$$

where $\triangle Y_{t+i}$ and $\triangle G_{t+i}^{I}$ are level changes in output and government investment relative to their steady state values. Discount factors are model-based, constructed from real interest rates along on the transition path. Compared with other measures of multipliers, such as peak responses to an initial change in a fiscal policy variable (as reported in Blanchard and Perotti (2002)) or period-by-period flow changes in government spending and output (as in Cogan, Cwik, Taylor, and Wieland (2009)), present-value multipliers better account for the dynamic effects of deficit-financed spending increases, particularly at longer horizons.

Table 3 reports the cumulative present-value multipliers for output, consumption, and investment based on the mean estimates, along with their 90-percent posterior intervals. We set $k = 1000$ in (19) to ensure that we account for all the dynamics following a government investment shock. Multipliers are computed for $\alpha^G = 0.05$ and 0.1 and under the three different implementation delays.

The productivity of public capital is the dominant factor determining cumulative multipliers for government investment, as seen in table 3. When $\alpha^G = 0.1$, multipliers are uniformly larger than when $\alpha^G = 0.05$, for a given length of implementation delay. A high stock of productive public capital has long-lasting effects on output. When government spending transforms into productive public capital, the cumulative output multiplier can be as large as 1.3 when $\alpha^G = 0.1$. Present-value consumption multipliers can also be positive because the positive wealth effect eventually dominates the short-run negative consumption response. Finally, we see that the present-value investment multipliers remain negative for all cases examined. For a given length of implementation delay, however, a larger α^G implies a less negative investment multiplier. Longer delays lead to more negative multipliers because there is a larger short-run dip in investment.

Neoclassical studies of government spending multipliers typically assume all spending is unproductive. The resulting negative wealth effect crowds out private consumption and investment. Those studies tend to infer that the output multiplier is less than 1 [for example, Leeper, Plante, and Traum (forthcoming) and Uhlig (2009)]. Our analysis shows that in a standard neoclassical growth model, the cumulative multiplier for output can still be larger than 1, even under distortionary financing and with a modest degree of productivity of public capital. Since recent countercyclical fiscal actions in the United State include substantial government investment projects, our results indicate that different government spending categories are likely to have very different multipliers, depending on the productivity of the spending.

Another common theme that emerges from existing work is that the stimulative effect of government spending is highest on impact and declines gradually afterwards. This typical pattern shows up in DSGE estimates in Forni, Monteforte, and Sessa (2009), Cogan, Cwik, Taylor, and Wieland (2009), and Zubairy (2009), as well as VAR estimates in Mountford and Uhlig (2009). This pattern provides some justification for relying on government spending to stimulate an economy in the short run. Under implementation delays and productive government spending, however, output multipliers can be relatively small at the beginning. Table 4 reports present-value mean output multipliers one year ($k = 5$) and three years ($k = 13$) after a government investment shock, to contrast them to long-run cumulative multipliers ($k = 1000$). When there is a one-quarter delay to build public capital, the typical pattern holds when government investment is weakly productive ($\alpha^G = 0.05$): the output multiplier declines over time, mainly due to subsequent expected fiscal adjustments. With longer delays, the output multipliers are relatively close over time. The reduction in output multipliers during the initial years results from implementation delays, which produce slightly negative or muted responses in output.

On the other hand, when government investment is more productive ($\alpha^G = 0.1$), we see that the patterns of output multipliers are generally reserved. Short-run output multipliers are much smaller than long-run multipliers. Even though government investment is more productive, the output multipliers after one year are smaller than those when $\alpha^G = 0.05$. More productive government investment generates stronger positive wealth effects, so labor rises less, investment falls more, and output rises less in the short run. This suggests that there is considerable uncertainty about the short-run expansionary effects of government investment, especially when a project involves substantial delay.

Multipliers in table 3 indicate quite a bit of uncertainty in assessing government investment. The 90-percent posterior intervals reflect estimation uncertainty conditional on the model specification in section 2; they do not, however, account for the model uncertainty. Leeper, Walker, and Yang (2009b) consider three alternative specifications: agents can derive utility from government consumption, private capital is also subject to a process of time-to-build, and the economy includes a government production section where the government employs workers and purchases goods to produce output. The multipliers for those calibrated models show that the basic messages conveyed in this analysis hold. In general, the more productive is government investment, the more favorable the growth effects and the more likely the cumulative consumption multiplier will be positive. And the shorter the implementation delay, the less negative is the cumulative investment multiplier.

6 Concluding Remarks

This paper studies the macroeconomic effects of government investment in light of implementation delays and distorting fiscal adjustments. A substantial time-to-build lag in a standard neoclassical model can make expansionary government investment contractionary in the short run, at worst, and have a muted impact, at best. Over longer horizons, 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. Macroeconomic analysis often does not distinguish among the various types of government spending. But present-value cumulative output multipliers can be larger than 1 even if government investment is only moderately productive.

To better connect our findings to existing literature, we employed a neoclassical framework that is completely standard in macroeconomic research and is within the class of models used in policy institutions around the world. Nonetheless, it has its limitations, particularly in addressing the circumstances surrounding the recession of 2007-2009. The model does not adequately capture many of the aspects of the U.S. economy that are likely to be important for predicting the consequences of the ARRA or other policy actions designed to lift the economy out of the 2007-2009 recession. For example, one characteristic of the macroeconomic policy response to the recession was that both fiscal policy and monetary policy reacted aggressively. In fact, the Federal Reserve drove the federal funds rate to its zero bound in its efforts to stimulate demand. Recent work has shown that government spending multipliers can be substantially larger when coupled with such a monetary policy response [see, for example, Christiano, Eichenbaum, and Rebelo (2009) and Davig and Leeper (2009) who study only unproductive government spending in models with nominal rigidities]. Traum and Yang (2009), though, integrate monetary and fiscal policy in an environment that differentiates between productive and unproductive government spending.

Because the ARRA includes substantial authorizations for infrastructure spending and the policy makers may consider more government investment to facilitate the economic recovery, this analysis can nevertheless highlight factors associated with expansions in government investment that are important for understanding the impacts and the limitations of government investment in the short run and the long run.

A Data Description

This appendix describes data used in the estimation. The data source, unless stated otherwise, is the National Income and Product Accounts compiled by the Bureau of Economic Analysis. Nominal values are converted to real values using the implicit price deflator for personal consumption expenditures (table 1.1.9 line 2). Fiscal variables include federal and state and local governments.

Consumption, investment, and hours worked are constructed following Leeper, Plante, and Traum (forthcoming). Consumption tax revenue is $C \times \tau^C$, where $\tau^C = \frac{T^C}{C-T^C}$ and T^C is taxes on production and imports less property taxes (table 3.1 line 4 and table 3.3 line 8). We follow Jones (2002) to construct capital and labor tax revenues. Government consumption, G^C, is defined as government consumption expenditure (table 3.1 line 16) and government net purchases of non-produced assets (table 3.1 line 37), minus government consumption of fixed capital (table 3.1 line 38). Government investment, G^I, is defined as government gross investment (table 3.1 line 35).

Transfers are defined as the sum of net current transfers, net capital transfers, and subsidies (table 3.1 line 25), minus the tax residual. Net current transfers are current transfer payments (table 3.1 line 17) minus current transfer receipts (table 3.1 line 11). Net capital transfers are defined as capital transfer payments (table 3.1 line 36) minus capital transfer receipts (table 3.1 line 32). The tax residual is the sum of current tax receipts (table 3.1 line 2), contributions for government social insurance (table 3.1 line 7), income receipts on assets (table 3.1 line 8), and the current surplus of government enterprises (table 3.1 line 14), minus total tax revenue (consumption, labor, and capital taxes).

Government debt at t is the sum of net borrowing at t and government debt at $t-1$ less seigniorage revenue. Net borrowing, consistent with the NIPA concept, is the sum of government consumption, government investment, transfers, and interest payment (table 3.1 line 22) less tax revenues, where tax revenues consist of consumption tax and capital and labor income tax.

For the estimation, all data series are scaled by a population index. Let X be an observable, then $X = \ln\left(\frac{x}{\text{Popindex}}\right) * 100$, where x is original data, and Popindex is an index of population (civilian noninstitutional population, ages 16 years and over, seasonally adjusted, U.S. Bureau of Labor Statistics, LNS10000000) with 1992Q3 = 1,

ARRA, Highway Construction in Title XII (billions)									
	2009	2010	2011	2012	2013	2014	2015	2016	2009-16
Budget Authority	27.5	0	0	0	0	0	0	0	27.5
Estimated Outlay	2.75	6.875	5.5	4.125	3.025	2.75	1.925	.55	27.5
National Highway Bridge Reconstruction and Inspection Act (millions)									
	2009	2010	2011	2012	2013				2009-13
Budget Authority	1,029	5	5	5	5				1,049
Estimated Outlay	280	425	169	56	46				976

Table 1: Cost estimation by the Congressional Budget Office.

Parameters	**Prior**			**Posterior**			
	func.	mean	std.	mean	5%	95%	std.
Structure							
γ, risk aversion	G	1.75	0.5	3.46	2.7	4.3	0.51
κ, inverse Frisch labor elast.	G	2	0.5	1.89	1.3	2.5	0.37
h, habit formation	B	0.5	0.2	0.31	0.22	0.41	0.06
δ_2, capital utilization	B	0.7	0.5	0.067	0.041	0.1	0.021
s, investment adj. cost	N	5	0.25	5.21	4.8	5.6	0.25
Fiscal policy							
γ_{GC}, govt consumption resp to debt	N	0.15	0.1	0.072	0.022	0.12	0.031
γ_K, capital tax resp to debt	N	0.15	0.1	0.095	0.033	0.16	0.037
γ_L, labor tax resp to debt	N	0.15	0.1	0.051	-0.023	0.12	0.045
γ_Z, transfers resp to debt	N	0.15	0.1	0.15	0.047	0.27	0.066
φ_K, capital resp. to output	G	1	0.3	1.2	0.91	1.5	0.19
φ_L, labor resp. to output	G	0.5	0.25	0.53	0.24	0.84	0.18
φ_Z, transfers resp. to output	G	0.2	0.1	0.23	0.082	0.43	0.11
AR(1) coeff. for exogenous variables							
ρ_a, technology	B	0.5	0.2	0.95	0.94	0.97	0.01
ρ_b, preference	B	0.5	0.2	0.78	0.74	0.83	0.026
ρ_l, leisure preference	B	0.5	0.2	0.99	0.99	1	0.0046
ρ_i, investment	B	0.5	0.2	0.24	0.18	0.3	0.038
ρ_{GC}, govt consumption	B	0.5	0.2	0.95	0.93	0.98	0.015
ρ_{GI}, govt investment	B	0.5	0.2	0.94	0.90	0.98	0.021
ρ_K, capital tax	B	0.5	0.2	0.89	0.84	0.93	0.027
ρ_L, labor tax	B	0.5	0.2	0.99	0.97	1	0.0093
ρ_C, consumption tax	B	0.5	0.2	0.88	0.83	0.94	0.033
ρ_Z, transfer	B	0.5	0.2	0.96	0.92	0.99	0.021
Std. of shocks							
σ_a, technology	IG	1	4	0.63	0.57	0.69	0.037
σ_b, preference	IG	1	4	2.35	2	2.7	0.2
σ_l, leisure preference	IG	1	4	2.82	2.3	3.4	0.34
σ_i, investment	IG	1	4	4.59	4.2	5	0.27
σ_{GC}, government consumption	IG	1	4	2.04	1.9	2.2	0.12
σ_{GI}, government investment	IG	1	4	3.17	2.9	3.4	0.16
σ_K, capital tax	IG	1	4	2.60	2.4	2.8	0.13
σ_L, labor tax	IG	1	4	2.91	2.7	3.2	0.15
σ_C, consumption tax	IG	1	4	1.25	1.1	1.4	0.065
σ_Z, transfers	IG	1	4	4.46	4.1	4.9	0.23

Table 2: Prior and posterior distributions for the estimated parameters. For function IG—the inverse Gamma distribution—values 1 and 4 correspond to s and v, where $f(x|s,v) = v^s\Gamma^{-1}(s)x^{-s-1}\exp^{\frac{-v}{x}}$

	Y	C	I	Y	C	I
		$\alpha^G = 0.05$			$\alpha^G = 0.1$	
1Q delay	0.39	−0.07	−0.35	1.14	0.43	−0.17
	$(0.01, 0.65)$	$(-0.16, 0.005)$	$(-0.59, -0.19)$	$(0.90, 1.34)$	$(0.35, 0.52)$	$(-0.32, -0.06)$
1Y delay	0.40	−0.08	−0.36	1.11	0.40	−0.20
	$(0.09, 0.63)$	$(-0.16, -0.02)$	$(-0.56, -0.21)$	$(0.92, 1.30)$	$(0.33, 0.49)$	$(-0.32, -0.10)$
3Y delay	0.31	−0.11	−0.40	0.90	0.32	−0.31
	$(-0.03, 0.57)$	$(-0.19, -0.05)$	$(-0.62, -0.24)$	$(0.68, 1.11)$	$(0.26, 0.41)$	$(-0.45, -0.20)$

Table 3: Present-value cumulative multipliers for an increase in government investment ($k = 1000$). The parentheses contain the 5th and 95th percentiles of multipliers of the posterior distribution.

	1Y after	3Y after	cumulative	1Y after	3Y after	cumulative
		$\alpha^G = 0.05$			$\alpha^G = 0.1$	
1Q delay	0.51	0.42	0.39	0.39	0.41	1.14
1Y delay	0.43	0.37	0.40	0.39	0.39	1.11
3Y delay	0.33	0.31	0.31	0.30	0.25	0.90

Table 4: Present-value output multipliers at various horizons: one year and three years after the shock, and cumulative multipliers ($k = 1000$). Calculation based on the mean estimates of parameters.

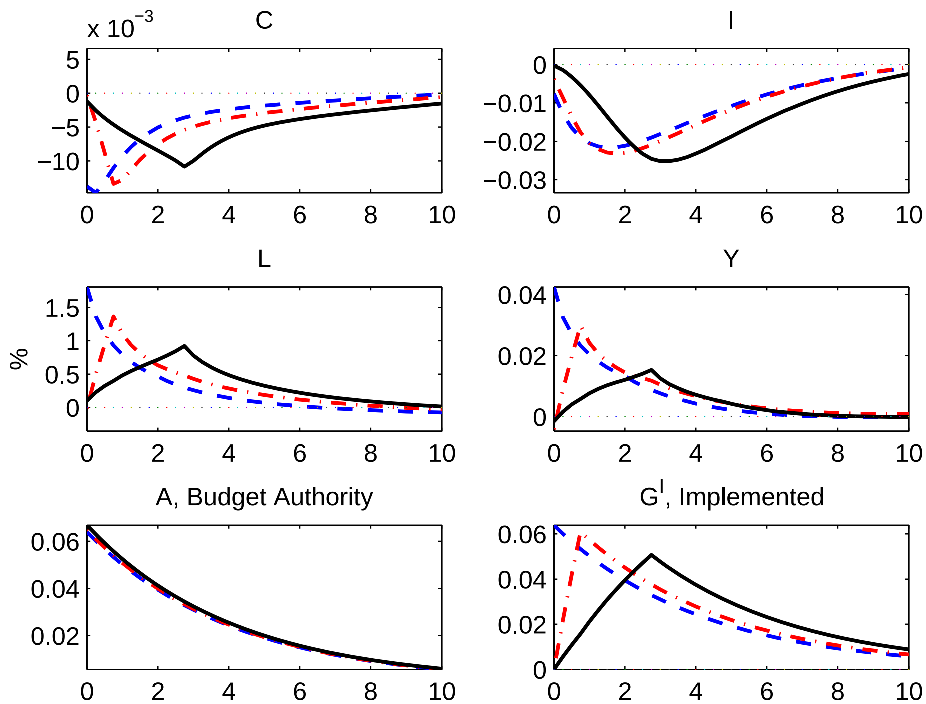

Figure 1: Impulse responses to higher government investment under various lengths of implementation delays. Dashed lines: one-quarter delay; dotted-dashed lines: one-year delay; solid lines: three-year delay. The area under G^I is one unit of good over the entire response horizon for all scenarios. All variables are in units of goods, except labor which is in percentage deviations from steady state. X-axis is in years.

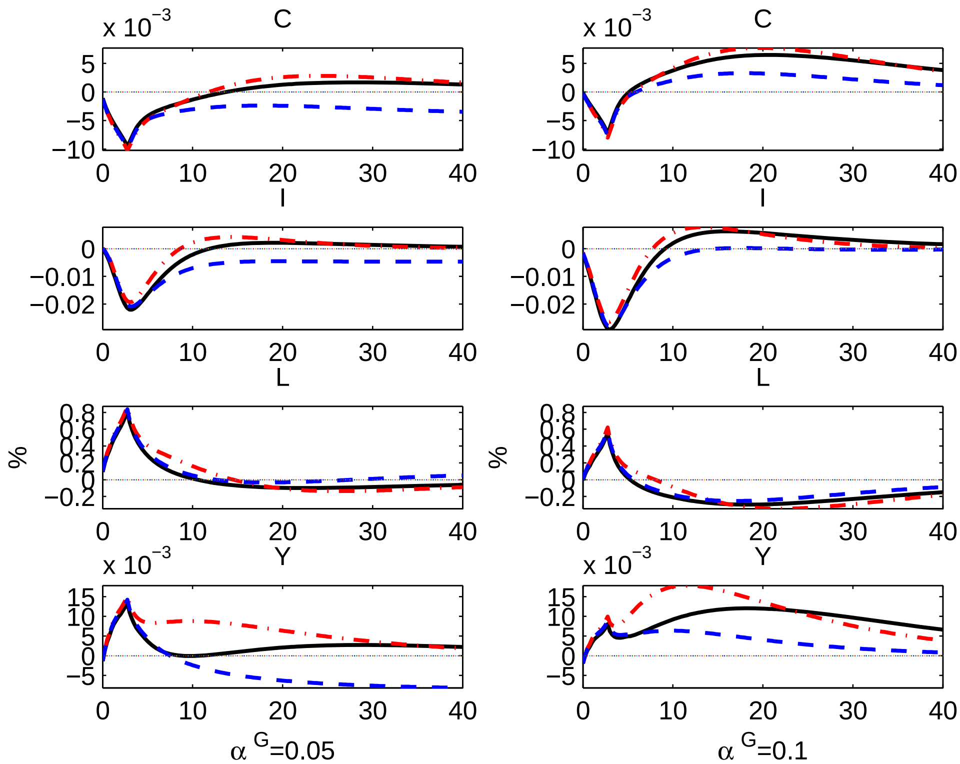

Figure 2: Impulse responses to an increase in government investment under various financing methods. Solid lines: all adjust under mean estimated debt financing parameters (as in table 2); dotted-dashed lines: only transfers adjust ($\gamma_Z = 0.154, \gamma_{GC} = \gamma_K = \gamma_L = 0$); dashed lines: only income taxes adjust ($\gamma_K = 0.142, \gamma_L = 0.077, \gamma_{GC} = \gamma_Z = 0$). The total increase in government investment is one unit of good. All variables are in units of goods, except labor which is in percentage deviations from steady state. X-axis is in years.

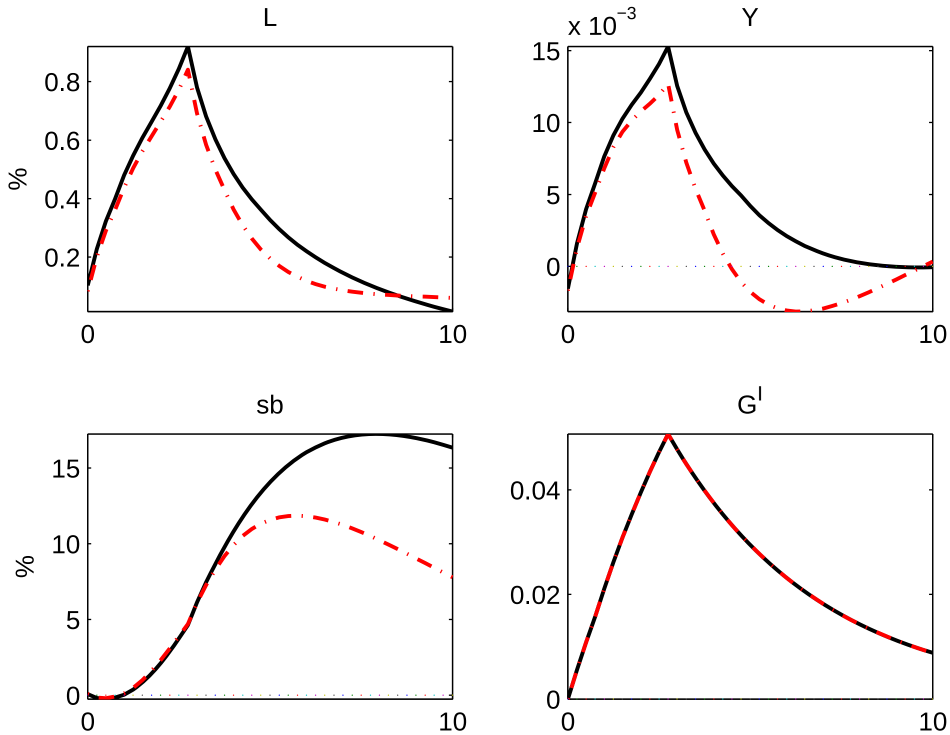

Figure 3: Impulse responses to an increase in government investment under different fiscal adjustment speeds. Solid lines: mean estimates as in table 2; dotted-dashed lines: faster adjustments.

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