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**Government Consumption and Investment:
Does the Composition of Purchases
Affect the Multiplier?**

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May 7, 2018

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Government Consumption and Investment: Does the Composition of Purchases Affect the Multiplier?*

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Abstract

I show that a large and conventional class of macroeconomic models predicts that short-lived government investment shocks have a much smaller fiscal multiplier than government consumption shocks. I test this prediction in a panel of OECD countries using real-time forecasts of government consumption and investment to purify changes in purchases of their predicted components. Consistent with theory, I estimate a government investment multiplier near zero and a government consumption multiplier of approximately 0.8. These findings suggest that fiscal stimulus packages which contain large government investment components may not be as effective at stimulating aggregate demand as commonly thought.

JEL Codes: E21, E32, E62, E63

Keywords: Fiscal multiplier, Durable goods, Investment, Government spending, Government investment, Government consumption

*Department of Economics, Austin, TX 78712. Email: chris.e.boehm@gmail.com. This paper supersedes the paper Government Spending and Durable Goods (Boehm, 2016). I would like to thank Chris House, Oli Coibion, Matthew Shapiro, Stefan Nagel, Joshua Hausman, and Edward Ionides for valuable comments, suggestions, and support. I also thank Saroj Bhattarai, Charlie Brown, Matias Cattaneo, Aaron Flaaen, Jordi Galí, Simon Gilchrist, Andy Glover, Jim Hamilton, Miles Kimball, David Lagakos, Andrei Levchenko, Ben Meiselman, Emi Nakamura, Pablo Ottonello, Nitya Pandalai-Nayar, Valerie Ramey, Dimitrije Ruzic, Richard Ryan, Jeff Smith, Isaac Sorkin, Johannes Wieland, and Justin Wolfers for helpful conversations as well as the participants of the seminars at Michigan, UIUC, the Bank of Canada, the Federal Reserve Board, CREI, Warwick, Cambridge, INSEAD, IIES, the Boston Fed, Notre Dame, Columbia, UT Austin, the San Francisco Fed, UCSD, Oregon, the EGSC in St. Louis, the Fall 2015 Midwest Macro Meeting in Rochester, and the 85th SEA Annual Meetings.

1 Introduction

During the Great Recession, a number of governments around the world enacted fiscal stimulus packages to combat the decline in economic activity. A common feature of these policies was a significant share of spending on long-lived investment goods. In the U.S., for instance, the American Recovery and Reinvestment Act contained provisions to raise spending in excess of 70 billion dollars on infrastructure and transportation.¹ In other countries infrastructure investment also constituted a significant fraction of stimulus spending, most notably China with approximately 40 percent (International Labour Organization, 2011). More generally, government investment features prominently in debates on fiscal stimulus where it is typically assumed to be highly effective (e.g. Krugman, 2016).

This paper studies the fiscal multiplier associated with government investment and compares it to the multiplier of government consumption spending. I first demonstrate that a large and conventional class of macroeconomic models predicts that the government investment multiplier is *small*—typically below 20 cents on the dollar. This contrasts with the government consumption multiplier which is between 0.6 and 1 under standard assumptions on parameters. I then estimate government consumption and investment multipliers in a panel of OECD countries. The data supports the theory’s predictions: I estimate a government consumption multiplier of around 0.8 and a government investment multiplier near zero. These findings suggest that government investment may not be as effective at raising output as is commonly assumed.

I begin in Section 2 with comparing the consumption and investment multiplier in a two-sector model. I show that the investment multiplier is so small because private investment falls drastically after government investment shocks. This high degree of crowding out is driven by the high intertemporal elasticity of substitution of investment demand which has been shown to be a feature of a large class of macroeconomic models (e.g., Mankiw, 1985, Erceg and Levin, 2006, Barsky, House, and Kimball, 2007, House and Shapiro, 2008, House, 2014, Barsky et al., 2015). Since a higher intertemporal elasticity of substitution is associated with a smaller wealth effect, temporary government investment shocks provide essentially no incentive for households to increase their labor supply.

In Section 3 I test this prediction, using data from the OECD’s Statistics and Projections

¹This information is taken from <http://www.recovery.gov/arra/Transparency/fundingoverview/Pages/fundingbreakdown.aspx>. Since the website is now offline, I accessed a cached version (from 01/04/2014) via <https://archive.org/>.

Database. This database not only includes separate series for government consumption and investment, but also real-time forecasts of these two components of spending. Building on Blanchard and Perotti (2002), Auerbach and Gorodnichenko (2012, 2013), Ramey and Zubairy (2017), and Miyamoto, Nguyen, and Sergeyev (2017), I develop a method to estimate separate multipliers for government consumption and investment. To address the concern that shocks identified with this scheme could be anticipated (Ramey, 2011b), I use the OECD's real-time forecasts to purge changes in purchases of their predicted components. Further, I restrict myself to the use of quarterly data (as in Ilzetki, Mendoza, and Végh, 2013), because the identification assumption requires that the government does not respond to changing economic conditions within the same period.

I estimate a government consumption multiplier of approximately 0.8 and a government investment multiplier near zero. As predicted by the model, the difference between these two multipliers is driven in large part by the fact that private investment falls after government investment shocks, but not after government consumption shocks. Private consumption remains broadly unchanged after either of the two shocks. The difference between the government consumption and investment multipliers is not driven by alternative financing schemes and survives a number of robustness checks.

The model predicts that private investment is crowded out through a rise in the own real interest rate of the investment goods sector. To test this hypothesis, I construct real interest rates using real-time forecasts of the sector-specific inflation rates from the OECD's Statistics and Projections database. Consistent with the model, there is evidence of a temporary rise in the own real interest rate of investment after a shock to government investment. The own real interest rate in the consumption goods sector responds insignificantly to a government consumption shock.²

I next test whether the government consumption and investment multipliers depend on 1) whether the economy is at the zero lower bound (ZLB) (e.g. Christiano, Eichenbaum, and Rebelo, 2011, Woodford, 2011) and 2) the state of the business cycle (e.g. Auerbach and Gorodnichenko, 2012, 2013). There is some evidence for larger multipliers at the ZLB, in particular for government consumption. Importantly, even at the ZLB government investment crowds out private investment. When I condition on the state of the business cycle, I find slightly smaller government investment multipliers during slumps, similar to Berger and Vavra (2014). However,

²Theory suggests that private sector spending could also be crowded in or out via alternative mechanisms. Michailat (2014), for instance, develops a model in which greater tightness crowds out private sector employment.

I prefer to interpret these results as merely suggestive, as there is no consensus in the literature on how the business cycle should be measured.

In Section 4 I show that the multiplier for *total* government purchases, which is commonly estimated in the literature, can suffer from external validity problems. Without any assumptions on the true macroeconomic environment, I show that the multiplier for total purchases is approximately a weighted average of the government consumption and investment multipliers. Broadly speaking, the weights reflect the composition of purchases. Since this composition can differ across applications, the multiplier for total purchases can vary—even if the multipliers of government consumption and investment remain unchanged. For instance, if an actual stimulus program has a different composition of government consumption and investment than the identifying variation for the estimated multiplier, then this estimate will provide misleading guidance for policy. Similarly, one would not expect that estimates for the multiplier of total purchases are necessarily comparable across samples and identification schemes.

This paper is related to a large literature on the effects of government spending. Influential theoretical work such as Aiyagari, Christiano, and Eichenbaum (1992) and Baxter and King (1993) emphasizes that the wealth effect is critical for determining the size of the fiscal multiplier and that investment is crowded out after temporary shocks to government purchases. Hall (2009) shows in a simple static model that the fiscal multiplier is decreasing in the intertemporal elasticity of substitution. In his model the multiplier tends to zero as the intertemporal elasticity of substitution approaches infinity. I show that the same result holds approximately in the model I present below.³ Cogan et al. (2010) document strong crowding-out of investment in a quantitative model. Neither of these papers studies government investment separately from government consumption in a two sector model.

The theoretical prediction that investment is crowded out after increases in the *sum of government consumption and investment* is commonly confirmed in the data. Ramey and Shapiro (1998), Blanchard and Perotti (2002), Mountford and Uhlig (2009), Barro and Redlick (2011), Ramey (2011b), and others all find that investment falls after such a shock.⁴ Relative to these papers, I argue that one should, if possible, distinguish between these two types of spending since government investment is more likely to crowd out private investment than government

³In his discussion of Hall's paper, House (2009) argues that falling investment after fiscal expansions is critical for determining the output responses in standard models.

⁴Edelberg, Eichenbaum, and Fisher (1999) find that residential investment falls but nonresidential investment increases.

consumption.⁵

Another strand of literature argues that public investment accumulates into a productive public capital stock (e.g. Aschauer, 1989a, 1989b, Pereira, 2000, Kamps, 2005).⁶ Motivated by this hypothesis Voss (2002), Perotti (2004), Pappa (2010), and others estimate separate multipliers for government consumption and government investment. Voss (2002) and Perotti (2004) find that government investment is associated with a small multiplier because private investment falls. While Perotti (2004, p. 26) views this evidence as a “puzzle”, I show below that a standard two-sector model predicts precisely that. The findings in Pappa (2010) are mixed. Neither of these papers makes a connection to the high intertemporal elasticity of substitution of investment. Since I have little to add to the hypothesis of productive government capital, and since my focus is on temporary stabilizing interventions, I shall ignore such long-run considerations in this paper.⁷ I provide concluding comments in Section 5.

2 Theoretical Analysis

I next present a two sector New Keynesian model to study the effectiveness of government consumption and investment at raising output. After describing the model, I lay out the main claim that under a conventional set of assumptions the government investment multiplier is small. I then discuss the mechanism and robustness. Since the model is fairly standard, I keep this section brief.

2.1 Model setup

Consumers Time is discrete and consumers’ life time utility is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(c_t^h)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \chi \frac{(g_t^h)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \phi \frac{n_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right]. \quad (1)$$

⁵For summaries of the literature, see Perotti (2008) and Ramey (2011a).

⁶Bouakez, Guillard, and Roulleau-Pasdeloup (2017) study public investment at the zero lower bound.

⁷A recent literature uses state-level variation to estimate fiscal multipliers. For instance, Cohen, Coval, and Malloy (2011) find that private investment is crowded out after fiscal expansions although this finding is contested in Snyder and Welch (2017). Leduc and Wilson (2012) estimate large multipliers for public infrastructure spending, particularly at long horizons. Since Nakamura and Steinsson (2014) show that such cross-sectional multipliers are not easily mapped to an aggregate multiplier, it is not clear whether the findings in Leduc and Wilson (2012) conflict with the estimates in this paper. Chodorow-Reich (2017) summarizes the literature on cross-sectional multipliers.

Here, c^h denotes the household's nondurable goods consumption and g^h is a composite of the government capital stock and government consumption. Since g^h enters additively in the utility function, it will not affect the equilibrium. Hence there is no need to specify how g^h depends on its components and how government investment accumulates into a capital stock. The labor aggregate n is composed of labor in the consumption goods sector n^c and labor in the investment sector n^x according to

$$n_t = \left[(n_t^c)^{\frac{\eta+\mu}{\eta}} + (n_t^x)^{\frac{\eta+\mu}{\eta}} \right]^{\frac{\eta}{\eta+\mu}}. \quad (2)$$

Note that this specification nests two canonical cases, depending on the choice of $\mu \in [0, 1]$. For $\mu = 0$, labor is fully mobile between sectors, and for $\mu = 1$, labor is perfectly immobile and enters separably in the utility function.

Households own the capital stocks of the two sectors and maximize (1) subject to the labor aggregator (2), the nominal budget constraint

$$b_t + p_t^c c_t^h + p_t^x (x_t^c + x_t^x) = b_{t-1} (1 + i_{t-1}) + \pi_t - \tau_t^l + \sum_{s \in \{c, x\}} w_t^s n_t^s + r_{k,t}^s k_t^s, \quad (3)$$

the accumulation equations

$$k_{t+1}^s = k_t^s (1 - \delta) + \vartheta \left(\frac{x_t^s}{k_t^s} \right) k_t^s, \quad s \in \{c, x\}, \quad (4)$$

and a no-Ponzi condition. x_t^s is investment in sector s and $\vartheta \left(\frac{x_t^s}{k_t^s} \right) k_t^s$ an adjustment cost function satisfying $\vartheta \left(\frac{x}{k} \right) = \frac{x}{k}$, $\vartheta' \left(\frac{x}{k} \right) = 1$, and $\vartheta'' \left(\frac{x}{k} \right) = -\zeta$ in the steady state. The remaining notation is as follows: b_t is a nominal bond, i_t the nominal interest rate, π_t are profits, and τ_t^l is a lump-sum tax which the government uses to finance both types of expenditures.

Let λ_t be the multiplier on the nominal budget constraint and $\lambda_t \gamma_t^s$ the multiplier on the accumulation equation in sector s , that is, γ_t^s is the dollar value of one unit of installed capital in sector s . Then optimal behavior requires that

$$\left(c_t^h \right)^{-\frac{1}{\sigma}} = p_{c,t} \lambda_t \quad (5)$$

$$\phi \left(n_t \right)^{\frac{1-\mu}{\eta}} \left(n_t^s \right)^{\frac{\mu}{\eta}} = \lambda_t w_t^s, \quad s \in \{c, x\} \quad (6)$$

$$p_t^x = \gamma_t^s \vartheta' \left(\frac{x_t^s}{k_t^s} \right), \quad s \in \{c, x\} \quad (7)$$

$$\lambda_t = \beta (1 + i_t) E_t [\lambda_{t+1}], \quad (8)$$

$$\lambda_t \gamma_t^s = \beta E_t \left[\lambda_{t+1} r_{k,t+1}^s + \lambda_{t+1} \gamma_{t+1}^s \left((1 - \delta) + \vartheta \left(\frac{x_{t+1}^s}{k_{t+1}^s} \right) - \vartheta' \left(\frac{x_{t+1}^s}{k_{t+1}^s} \right) \frac{x_{t+1}^s}{k_{t+1}^s} \right) \right], \quad s \in \{c, x\}. \quad (9)$$

Firms Both sectors have a competitive aggregating firm and a unit continuum of differentiated firms which compete monopolistically. The aggregating firm in sector $s \in \{c, x\}$ assembles the varieties into the sector's output using a CES aggregator with elasticity ε , $s_t = \left[\int_0^1 (s_{j,t})^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}$. Optimal behavior yields the demand curves

$$s_{j,t} = s_t \left(\frac{p_{j,t}^s}{p_t^s} \right)^{-\varepsilon}, \quad \text{for all } j, \quad (10)$$

and the price index $p_t^s = \left(\int_0^1 (p_{j,t}^s)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$.

Monopolistic competitors operate Cobb-Douglas production functions

$$s_{j,t} = (k_{j,t}^s)^\alpha (n_{j,t}^s)^{1-\alpha}, \quad s \in \{c, x\}, \quad (11)$$

and minimize costs, taking the sector-specific factor prices $r_{k,t}^s$ and w_t^s as given. Nominal marginal costs in sector $s \in \{c, x\}$ are

$$mc_t^s = \left(\frac{r_{k,t}^s}{\alpha} \right)^\alpha \left(\frac{w_t^s}{1-\alpha} \right)^{1-\alpha},$$

and factor demands conditional on marginal costs satisfy

$$\frac{w_t^s}{p_t^s} = \frac{mc_t^s}{p_t^s} (1 - \alpha) (k_{j,t}^s)^\alpha (n_{j,t}^s)^{-\alpha}, \quad (12)$$

$$\frac{r_{k,t}^s}{p_t^s} = \frac{mc_t^s}{p_t^s} \alpha (k_{j,t}^s)^{\alpha-1} (n_{j,t}^s)^{1-\alpha}. \quad (13)$$

Price setting Let $m_{t,t+\tau}$ be the stochastic discount factor for nominal cash flows. Firms set prices as in Calvo (1983), choosing $p_{j,t}^s$ to maximize

$$E_t \left[\sum_{\tau=0}^{\infty} (\theta_s)^\tau m_{t,t+\tau} [p_{j,t}^s s_{j,t+\tau} - mc_{t+\tau}^s s_{j,t+\tau}] \right]$$

subject to the sequence of demand curves (10). θ_s parameterizes price stickiness in sector s . The optimal reset price is

$$p_t^{s*} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{\tau=0}^{\infty} (\theta_s)^\tau m_{t,t+\tau} s_{t+\tau} (p_{t+\tau}^s)^\varepsilon m c_{t+\tau}^s}{E_t \sum_{\tau=0}^{\infty} (\theta_s)^\tau m_{t,t+\tau} s_{t+\tau} (p_{t+\tau}^s)^\varepsilon}.$$

Closing the model Markets in both sectors clear

$$\begin{aligned} x_t &= x_t^x + x_t^c + x_t^g, \\ c_t &= c_t^h + c_t^g, \end{aligned}$$

and government spending in each sector follows AR(1) processes

$$s_t^g = (1 - \varrho_s^g) s^g + \varrho_s^g s_{t-1}^g + \varepsilon_{s,t}^g, \quad s \in \{c, x\}.$$

The government finances spending with a contemporaneous lump-sum tax $\tau_t^l = p_t^x x_t^g + p_t^c c_t^g$. Letting p^x and p^c denote steady state prices, real GDP is $y_t = p^x x_t + p^c c_t$ and the deflator $p_t = (p_t^x x_t + p_t^c c_t) / y_t$. The central bank follows a Taylor rule of the form

$$i_t = \beta^{-1} - 1 + \phi_\pi \pi_t, \tag{14}$$

where π_t is inflation of the GDP deflator. The government consumption and investment multipliers are defined as $m_c := \frac{dy_t}{dp^c c_t^g}$ and $m_x := \frac{dy_t}{dp^x x_t^g}$.

2.2 A numerical example

I begin with a numerical example which illustrates the main claim and subsequently discuss the mechanism. For the numerical example, I choose parameters symmetrically for the consumption and investment goods sector to highlight that the results are driven by the long service life of capital goods and not other factors. The time period is a quarter and households discount the future with a discount factor β of 0.995. Labor is immobile across sectors so that $\mu = 1$. Consistent with recent estimates, I set the intertemporal elasticity of substitution σ to 0.25 (e.g. Cashin and Unayama, 2016), and the Frisch labor supply elasticity η to 0.75 (Chetty et al., 2011). I further set $\alpha = 1/3$ and choose a depreciation rate δ of 0.025. Following Basu and Leo (2016) who calibrate a similar model to match investment volatility in the data, I set the

adjustment cost parameter ζ to 2. To match the estimates in Section 3, I choose the persistence of government spending so that fiscal shocks decay to about one third after 2 years. This requires $\varrho_x^g = \varrho_c^g = 0.86$. Based on the 2005 U.S. national accounts, I set the government's share of purchases in the two sectors to $s_c^g = s_x^g = 0.175$. Finally, I select Calvo parameters θ_x and θ_c of 0.7, implying an approximate half-life of 6 months. Although most central banks target consumer price inflation, I prefer a benchmark parameterization which treats both sectors symmetrically and assume that the central bank responds to deflator inflation with a coefficient of ϕ_π of 1.5. Below, I discuss an alternative calibration which takes this and other asymmetries between the consumption and investment goods sector into account. Appendix A Table A1 summarizes this benchmark calibration.

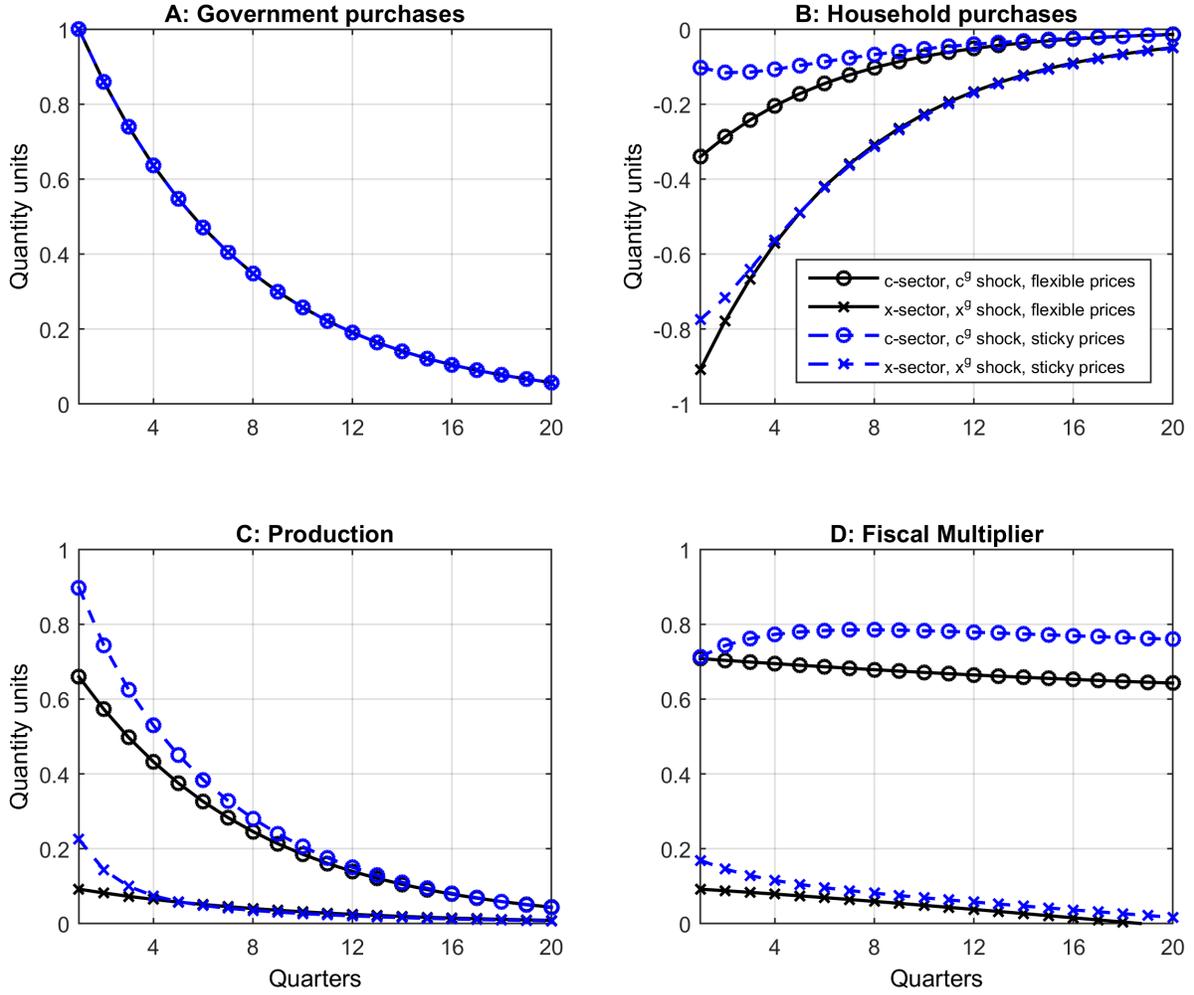
Figure 1 shows the impulse response functions to an increase in government spending by one quantity unit. In the figure, circles indicate responses to a government consumption shock and crosses indicate responses to a government investment shock. Panel B shows purchases of the household. In response to the increase in government consumption, household consumption c_t^h drops mildly, in the order of 0.1 to 0.35 quantity units, depending on whether prices are sticky. In stark contrast, private investment $x_t^c + x_t^x$ drops by approximately 0.8 to 0.9 quantity units when the government purchases the investment good. Put differently, private sector spending is crowded out to a much larger degree when spending occurs in the x-sector.

Because private investment contracts more than consumption after government spending shocks, production expands less in the investment sector. This is shown in Panel C. Panel D plots the multipliers associated with government consumption and government investment. The key conclusion is that the investment multiplier is small relative to the consumption multiplier. Price stickiness has quantitatively small effects in this example.

2.3 The mechanism

The large difference between the consumption multiplier and the investment multiplier ultimately follows from the long service life of capital goods. While nondurable goods are consumed within the same quarter, capital goods deliver service flows until fully depreciated. In what follows, I link the small government investment multiplier to two closely related properties of capital goods which are well understood in the literature (Barsky, House, and Kimball, 2007). First, the shadow value of capital responds very little to temporary shocks and second investment is highly

Figure 1: Impulse response functions



Notes: The figure plots the impulse response functions for a one unit increase in government spending based on the baseline calibration. Circles indicate responses to a government consumption shock and crosses indicate responses to a government investment shock.

intertemporally substitutable.

2.3.1 The nearly constant shadow value of capital

Assume for simplicity that there are no adjustment costs (ϑ is the identity), and that labor is immobile across sectors ($\mu = 1$). In the absence of adjustment costs, equation (9) can be solved

forward to obtain

$$\lambda_t \gamma_t^x = \beta E_t \left[\sum_{\tau=0}^{\infty} [\beta (1 - \delta)]^\tau \lambda_{t+\tau+1} r_{k,t+\tau+1}^x \right]. \quad (15)$$

Since $\lambda_t \gamma_t^x$ depends on service flows far in the future, it responds very little to temporary shocks. Such shocks only affect the first few terms in the infinite sum. As δ approaches zero and β tends to 1, the household places sufficient weight on future flows that approximating $\lambda_t \gamma_t^x$ with the steady state value becomes arbitrarily precise (Barsky, House, and Kimball, 2007, House and Shapiro, 2008).

To see how this matters for the government investment multiplier, combine equations (5 - 7) to obtain the labor supply conditions

$$\phi (n_t^c)^{\frac{1}{\eta}} = (c_t^h)^{-\frac{1}{\sigma}} \frac{w_t^c}{p_t^c}, \quad (16)$$

$$\phi (n_t^x)^{\frac{1}{\eta}} = \lambda_t \gamma_t^x \frac{w_t^x}{p_t^x}. \quad (17)$$

For the consumption goods sector, the wealth effect is $(c_t^h)^{-\frac{1}{\sigma}}$. If public consumption crowds out private consumption, households increase their labor supply. This “impoverishment” effect has been highlighted in, for instance, Aiyagari, Christiano, and Eichenbaum (1992) and Baxter and King (1993). However, the model predicts that the wealth effect is extremely weak in the investment goods sector. After a government investment shock, even if investment is crowded out, the shadow value of capital remains approximately unchanged. With $\lambda_t \gamma_t^x$ approximately constant, the household does not find it worthwhile to increase the supply of labor. I conclude that the near-constancy of the shadow value of capital essentially eliminates the wealth effect after government investment shocks.

Suppose we approximate $\lambda_t \gamma_t^x$, k_t^x , and k_t^c with their steady state values. Then, combining (17) with (12) gives

$$\phi (n_t^x)^{\frac{1}{\eta}} \approx \lambda \gamma^x \frac{m c_t^x}{p_t^x} (1 - \alpha) (k^x)^\alpha (n_t^x)^{-\alpha}.$$

In words, labor in the investment goods sector is only a function of the markup in the investment goods sector. Employment only rises if the markup falls in this approximation. A particularly striking case arises when prices are flexible. Since the markup is constant, labor and production in the investment goods sector remain approximately constant after a shock to government investment. As Proposition 2.1 shows under a somewhat more general set of assumptions, the

government investment multiplier is zero in this environment. This contrasts to the government consumption multiplier, which is positive but smaller than one.

Proposition 2.1. *Consider the model in Section 2.1 and suppose prices are flexible. Suppose further that δ is arbitrarily close to zero. Then, for a short-lived increase in spending ($q_x^g = q_c^g = 0$),*

$$m_x \approx 0, \tag{18}$$

$$m_c \approx \frac{(1 - \alpha) \left(\frac{\mu}{\eta} + \alpha \right)}{(1 - \alpha) \left(\frac{1 - \mu}{\eta} s_y^x + \frac{\mu}{\eta} + \alpha \right) + (1 - s_c^g) \sigma \left(\frac{\mu}{\eta} + \alpha \right) \left(\alpha + \frac{1}{\eta} \right)}. \tag{19}$$

Proof. See Appendix A.2.1 □

As is intuitive, the government consumption multiplier is increasing in the labor supply elasticity η , decreasing in the capital share α , and increasing in s_c^g .⁸ The consumption multiplier is also decreasing in the intertemporal elasticity of substitution σ . As $\sigma \rightarrow \infty$, the multiplier approaches zero. Note that the multiplier's dependence on the intertemporal elasticity of substitution follows from the fact that σ parameterizes the strength of the wealth effect (see equation 16). For large σ the labor supply becomes independent of the household's consumption. Since the intertemporal elasticity of substitution is extremely high for investment goods, the multiplier must be small. I next discuss an alternative interpretation which more directly highlights the role of the intertemporal elasticity of substitution.

2.3.2 The intertemporal elasticity of substitution of investment

Unlike consumption of nondurable goods, investment into durable goods and capital is highly interest-elastic. Because the service flow of capital depends on the stock and new investment constitutes a small fraction of next period's capital stock, households are much more willing to change the timing of investment in response to price changes than to change their consumption. One way

⁸The consumption multiplier is also decreasing in factor mobility (smaller μ). The intuition is that government consumption crowds out private investment when factors are mobile. In the benchmark case with labor immobility ($\mu = 1$), the consumption multiplier becomes, as in Hall (2009),

$$m_c \approx \frac{(1 - \alpha)}{(1 - \alpha) + (1 - s_c^g) \sigma (\alpha + \eta^{-1})}.$$

to make this statement precise is to consider the partial elasticities of consumption and investment with respect to their own real interest rates (defined as $1+r_t^s = (1+i_t)/E_t[1+\pi_{t+1}^s]$, $s \in \{c, x\}$).

Combining equations (4, 5, 7, 8, 9, and 13), and assuming that next period's labor n_{t+1}^s , investment x_{t+1}^s , $s \in \{c, x\}$, consumption c_{t+1}^h , and the relative price $\frac{p_{t+1}^x}{p_{t+1}^c}$ are held constant, these partial elasticities are

$$\frac{\partial \ln c_t^h}{\partial r_t^c} = -\sigma\beta, \quad (20)$$

$$\frac{\partial \ln x_t^s}{\partial r_t^x} = -\frac{1}{(1-\alpha)(\beta^{-1}-1+\delta)\delta + \zeta\delta(\beta^{-1}+\delta)}, \quad s \in \{c, x\}. \quad (21)$$

In the benchmark calibration $\frac{\partial \ln c_t^h}{\partial r_t^c} = -0.25$ and $\frac{\partial \ln x_t^s}{\partial r_t^x} = -19.23$. The difference of approximately factor 80 stems from the fact that the depreciation rate δ and the rate of time preference $\beta^{-1}-1$ in the denominator of (21) are small. Further, the dependence on these two parameters highlights that it is precisely the long service life that drives both the high elasticity and ultimately the small multiplier.

Figure 2 illustrates how this elasticity effects the equilibrium after an increase in government spending. Notice that the figure assumes that both sectors have the same supply elasticities.⁹ Because demand is so elastic, identical increases in the own real interest rates lead to much larger contractions of private investment. This makes the government investment multiplier small.

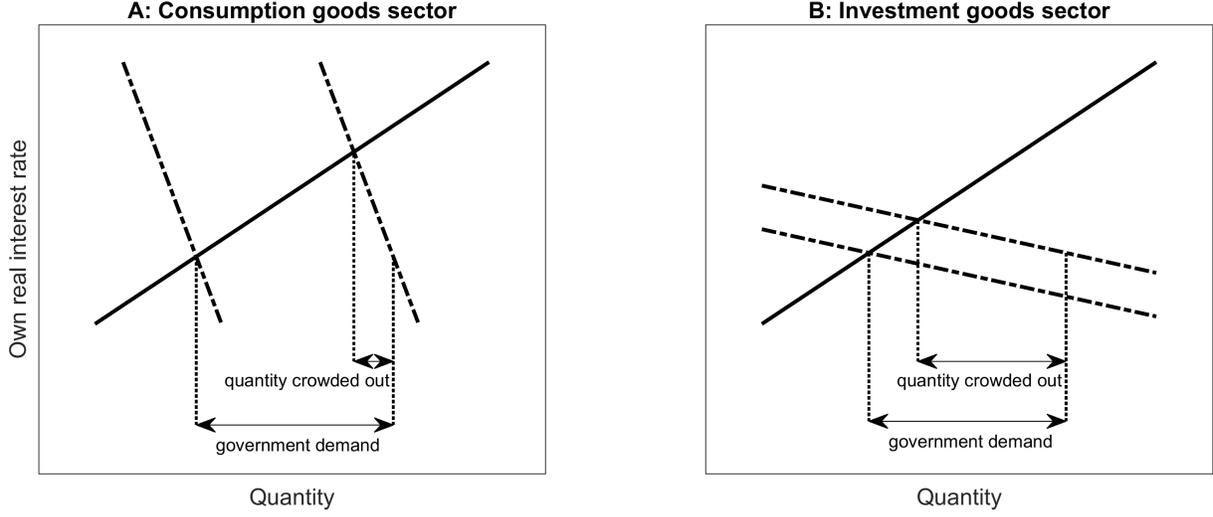
This mechanism also provides useful intuition for Proposition 2.1: As higher demand in the investment goods sector threatens to raise the own real interest rate, the private sector postpones purchases to the future. In the limiting approximation, private investment demand is infinitely elastic so that the demand curve is horizontal ($\delta \rightarrow 0$ in equation 21). As a result investment falls one for one with increased government spending and the real interest rate remains the same. Instead of buying the investment good the household hands the resources to the government (which then buys the investment good). Total output in the investment goods sector remains unchanged, and, in fact, no other variable changes in equilibrium.¹⁰

Figure 2 highlights the role of prices for crowding out private sector spending. It is the increase in the own real interest rate that leads to the contraction of private spending. In Section 3 I will test the prediction that prices and real interest rates rise after a government spending shock.

⁹Equal elasticities follow from the symmetric setup, in particular, the production functions and labor supply. See Appendix A.4 for details.

¹⁰I discuss the mathematical details in Appendix A.5.

Figure 2: Crowding out of private sector spending



To have a benchmark, Appendix A.6 reports the impulse response functions after government spending shocks. Note that the model predicts larger increases in the price level and real interest rate in the consumption goods sector.

2.3.3 Long-lived spending shocks

All results I have presented this far rely on the shock being transitory. Long-lived shocks have a larger effect on household wealth and leave less room for intertemporal substitution. Further, the capital stock adjusts more to persistent changes in investment. The multiplier for government investment is 1) larger, and 2) closer to the government consumption multiplier after long-lived shocks.

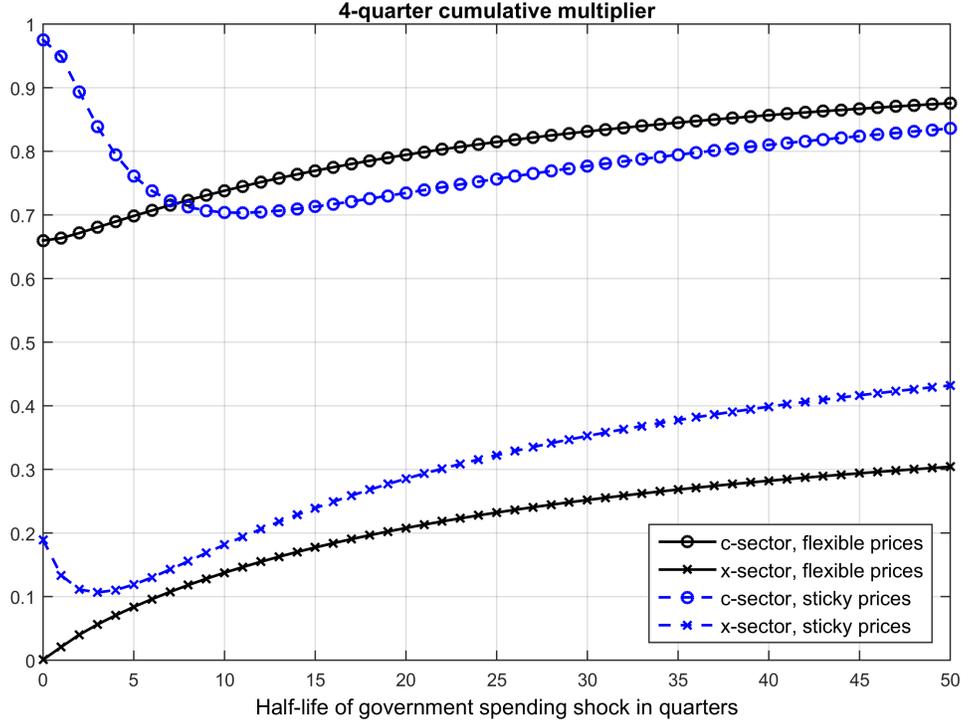
Proposition 2.2 reports the long-run government consumption and investment multipliers for permanent shocks. Because this proposition focuses on the long run (this is a steady state comparison), I assume that labor moves freely across sectors.

Proposition 2.2. *Consider the model Section 2.1 and assume that labor is mobile across sectors ($\mu = 0$). Then the long-run multipliers are*

$$m_c^\infty = m_x^\infty = \frac{\eta}{\sigma(1 - s_y^x)(1 - s_c^g) + \eta[1 - s_y^x(1 - s_x^g)]},$$

where s_y^x denotes the steady state share of the investment sector in GDP.

Figure 3: Short-run multipliers and shock persistence



Notes: The figure plots the 4-quarter cumulative multipliers using the benchmark calibration except for the shock persistence which is chosen to generate the half-lives as indicated on the horizontal axis.

Proof. See Appendix A.2.2. □

Note that long-run multipliers can be greater than one. In the baseline calibration with permanent shocks, $m_c^\infty = m_x^\infty \approx 1.1$.

Returning to the case with immobile labor ($\mu = 1$), I next illustrate how the *short-run* multipliers depend on shock persistence. Figure 3 plots 4-quarter multipliers for alternate half-lives of the government spending shock. The figure is based on the benchmark calibration except that ϱ_x^g and ϱ_c^g are chosen to generate the half-lives as indicated on the horizontal axis. While the investment multiplier is always smaller than the consumption multiplier, the difference depends on the persistence of the shock. For entirely transient government spending shocks, the difference is about 0.8 in the sticky-price model. For long-lived shocks, it is closer to 0.4. I conclude that the difference between the government consumption and investment multiplier should be harder to identify in the data when shocks are long-lived.

Table 1: Multipliers with and without high adjustment costs

	4-quarter multipliers			
	Baseline calibration $\zeta = 2$		High adjustment costs $\zeta = 156.1$	
	flexible prices	sticky prices	flexible prices	sticky prices
Government consumption multiplier	0.69	0.77	0.68	0.90
Government investment multiplier	0.08	0.12	0.65	0.79

Notes: The table reports the cumulative multipliers at a 4 quarter horizon. The multipliers are based on the benchmark calibration except that ζ is set to 156.1 in the high adjustment costs case.

2.4 Robustness

It is clear that the model is much too stylized to be taken literally. I present it here because it makes a relevant prediction for fiscal policy which should be tested in the data. I briefly discuss the robustness of this prediction.

2.4.1 Adjustment costs

The easiest way to break the result is to introduce extremely high investment adjustment costs. If the adjustment cost parameter ζ is infinite, then investment is constant, and the investment multiplier close to one. However, high adjustment costs also produce low investment volatility and potentially counterfactually low investment volatility. In the data, fixed investment is approximately 3 times as volatile as GDP, which naturally puts an upper bound on how high adjustment costs can be.

One can ask how high ζ must be to generate an investment multiplier that is similar to the government consumption multiplier. One simple way to do this is to choose ζ so as to equate the partial elasticities of consumption and investment with respect to their own real interest rate (equations 20 and 21). Using the benchmark calibration, ζ must be set to 156.1 to generate the same partial elasticity. The multipliers for this case are indeed close together and reported in Table 1. While a value of $\zeta = 156.1$ is presumably too high to be realistic, it is clear that moderate values of ζ above 2 can shrink the difference between the government consumption and investment multiplier.

Although I have relied on the standard convex adjustment cost framework for tractability, a number of papers have demonstrated that these models exhibit very similar aggregate dynamics as models that are more consistent with evidence on plant-level investment behavior, once analyzed in general equilibrium (Thomas, 2002, Veracierto, 2002). House (2014) shows that models with fixed costs of investment also exhibit the high interest elasticity of neoclassical investment models. This fact implies that the small government investment multiplier is more general than the specific framework adopted here.

2.4.2 Distortionary taxes and non-Ricardian consumers

I have this far assumed that the government finances spending with contemporaneous non-distortionary taxes — a canonical starting point. Relaxing this assumption can have large effects on the fiscal multiplier. For instance, Baxter and King (1993) show that financing spending with a distortionary tax on output reduces the size of the multiplier. Further, with distortionary taxes or hand-to-mouth consumers Ricardian equivalence ceases to hold, and it begins to matter whether spending is financed by issuing debt or raising current revenues (e.g. Galí, López-Salido, and Vallés, 2007).

Since in theory the financing decision of government expenditures is orthogonal to whether the government purchases consumption or investment goods, I do not present an exhaustive discussion of the effects on the two multipliers here. I do, however, note two caveats. First, contemporaneous tax changes which affect the intertemporal price of investment goods have large effects in these frameworks. The reason is that investment responds to such tax changes with the same high intertemporal elasticity of substitution that is responsible for the small government investment multiplier (House and Shapiro, 2008). Second, it is likely that, in practice, investment is more frequently financed with borrowed funds than government consumption. To the extent that taxes are distortionary or households non-Ricardian, this could affect estimates of fiscal multipliers. In the empirical section below I will discuss this concern extensively.

2.4.3 A non-symmetric calibration

While I preferred a symmetric benchmark calibration which highlights that the different multipliers arise from the long service life of capital goods, there exist other differences between consumption and investment goods in the data. In Appendix A.3 I replicate Figures 1 and 3

for a calibration which takes into account that 1) government consumption shocks as identified in Section 3 are more persistent, 2) the government purchases a slightly larger share from the consumption goods sector, 3) durable goods have less sticky prices, and 4) the Federal Reserve targets personal consumption expenditure inflation rather than GDP deflator inflation. The model's predictions for the two multipliers change very little.

As noted above, I continue to abstract here from the possibility that government spending is productive, as the focus of this paper is on the short run. Changing this assumption and adding the government capital stock into the production function(s) as in Baxter and King (1993) would increase the size of the government investment multiplier in the long run.

3 Empirical evidence

The main objective of this section is to test whether the data support the hypothesis that the investment multiplier is smaller than the consumption multiplier. The answer is broadly positive.

3.1 Data

My primary source of data are various editions of the OECD Economic Outlook's Statistics and Projections Database. The data covers the member countries and a handful of large developing economies. From 2003 onwards the data is available at a quarterly frequency. Editions published prior to 2003 only contain semiannual data. Since the identification assumption will require that the government does not respond to changing economic conditions within the same period, I construct a quarterly panel from 2003 to 2016.

For most countries the dataset contains separate series for government consumption and government investment. Further, for a subset of countries and periods, the OECD constructs forecasts of government consumption and government investment. These forecasts are published biannually and include information up until the 6th month of the semester. The OECD describes its forecasts as combining "expert judgement with a variety of existing and new information relevant to current and prospective developments".¹¹ Lenain (2002) and Vogel (2007) find that the OECD's forecasts broadly perform similar to private sector forecasts. I will use these forecasts to address the concern that shocks constructed from the Blanchard-Perotti identification scheme

¹¹See also <http://www.oecd.org/eco/outlook/forecastingmethodsandanalyticaltools.htm>. Last accessed 02/26/2018.

Table 2: Government consumption and investment shares

Country	Observations	Government share in consumption goods sector (percent)	Government share in investment goods sector (percent)
Australia	52	24.1	8.3
Belgium	50	30.1	8.3
Canada	52	25.7	12.0
Germany	52	24.1	8.0
Denmark	40	34.7	8.4
Finland	52	30.1	12.9
France	52	29.5	16.4
United Kingdom	52	25.3	11.4
Ireland	28	25.7	13.1
Japan	52	24.0	20.4
Korea	52	21.2	18.2
Netherlands	52	32.8	17.4
Norway	52	32.2	12.5
New Zealand	52	23.4	19.1
Portugal	18	24.6	13.2
Sweden	52	36.0	16.0
United States†	52	18.4	16.1
mean		27.2	13.6

Notes: Data are from the OECD Economic Outlook: Statistics and Projections Database. The countries are those included in the baseline sample.

†: The fraction of government investment in total investment in the OECD data differs slightly from the U.S. National Income and Product Accounts, Tables 1.1.5 and 3.9.5, which is 16.9.

could be anticipated (Ramey, 2011b). Since not accounting for such anticipation effects can lead to downward-biased estimates (Ramey, 2009), I drop observations for which these forecasts are not available.

As in the model, I define the consumption goods sector as including household consumption and government consumption, and the investment goods sector as including private and public investment. Table 2 lists the countries in the sample, together with their 2005 shares of government purchases in the two sectors. The government's share in the consumption goods sector averages 27.2 percent and varies moderately across countries. The government's share in the investment goods sector is lower and averages 13.6 percent in the sample. It also varies more across countries with 8 percent in Germany and 20.4 percent in Japan.

3.2 Empirical methodology

My empirical methodology builds on Blanchard and Perotti (2002) and numerous studies thereafter. The key identifying assumption is that the government does not respond to new information about the state of the business cycle within the same quarter. To address Ramey’s (2011b) critique that shocks from this scheme could be anticipated, I follow Auerbach and Gorodnichenko (2012, 2013), and Miyamoto, Nguyen, and Sergeyev (2017) and purify changes in government purchases of their predicted components. In particular, I implement the following two step procedure.

In the first step of the empirical analysis I estimate the regressions

$$\frac{s_{i,t}^g - s_{i,t-1}^g}{y_{i,t-1}} = \beta_c^s F_{t-1} \frac{c_{i,t}^g - c_{i,t-1}^g}{y_{i,t-1}} + \beta_x^s F_{t-1} \frac{x_{i,t}^g - x_{i,t-1}^g}{y_{i,t-1}} + \text{controls} + \gamma_i^s + \delta_t^s + \tau_i^s t + u_{i,t}^s, \quad s \in \{c, x\}. \quad (22)$$

The left hand side variable is the change in per capita government purchases in country i and sector s , divided by real per capita GDP in $t - 1$. F_{t-1} denotes the forecast.¹² The spending variable is then regressed on the forecasts of government spending in the consumption and investment goods sectors, a number of control variables, as well as country fixed effects, time fixed effects, and a linear country-specific time trend. Note that the division by lagged GDP which I will use throughout avoids the potentially problematic ex-post conversion from elasticities to currency units (Ramey and Zubairy, 2017).

The baseline control variables include four lags of the changes in real per capita private consumption, public consumption, private investment, public investment, and GDP, all divided by real per capita GDP in $t - 1$. They further include four lags of the unemployment rate, the growth rate of the GDP deflator, and the change in per capita government revenues relative to per capita GDP. Finally, because the countries in the sample are heterogeneous in their openness to trade, I control for lagged openness defined as imports plus exports divided by GDP. All real variables use the corresponding deflator. I construct private investment from total investment and government investment using the method in Whelan (2000).¹³ Details are available in Appendix B.

I use the residuals of equation (22), $\hat{u}_{i,t}^c$ and $\hat{u}_{i,t}^x$, as government spending shocks. They

¹²Because the OECD publishes new editions of the dataset only biannually, I have the $t - 1$ forecast only for the first and third quarter of each year. Forecasts for the second and fourth quarter are based on information available in $t - 2$.

¹³It would be interesting to study which components of investment (e.g. structures, equipment, inventories) are affected in the data. Unfortunately, the data from the OECD for these components are highly incomplete and cannot be used for this purpose.

are neither contemporaneously correlated with one another ($\rho(\hat{u}_{i,t}^c, \hat{u}_{i,t}^x) = 0.034$), nor are they autocorrelated ($\rho(\hat{u}_{i,t}^c, \hat{u}_{i,t-1}^c) = -0.037$, $\rho(\hat{u}_{i,t}^x, \hat{u}_{i,t-1}^x) = 0.004$). None of these correlations is significant at the 20 percent level. I note, however, that the non-purified changes in purchases $\frac{c_{i,t}^g - c_{i,t-1}^g}{y_{i,t-1}}$ and $\frac{x_{i,t}^g - x_{i,t-1}^g}{y_{i,t-1}}$ are correlated ($\rho = 0.059$) over the period from 1980 to 2016. Further, their forecasts in the actual sample are correlated ($\rho = 0.156$). Both correlations are significant at the 1 percent level. This suggests that it is, in general, more prudent to analyze government consumption and investment jointly. I present histograms of the shocks $\hat{u}_{i,t}^c$ and $\hat{u}_{i,t}^x$ in Figure C1 of Appendix C.

In a second step I estimate impulse response functions and fiscal multipliers. I estimate impulse response functions using Jordà's (2005) method. In particular, and letting v denote a generic variable of interest, I estimate

$$\frac{v_{i,t+h} - v_{i,t-1}}{y_{i,t-1}} = \alpha_c^h \hat{u}_{i,t}^c + \alpha_x^h \hat{u}_{i,t}^x + \text{controls} + \gamma_i^h + \delta_t^h + \tau_i^h t + \varepsilon_{i,t+h}^v \quad (23)$$

for $h = 0, \dots, H$. The parameters $\{\alpha_c^h\}_{h=0}^h$ and $\{\alpha_x^h\}_{h=0}^h$ are the impulse response coefficients for government consumption and investment shocks.¹⁴

Further, and following Ramey and Zubairy (2017), I estimate

$$\begin{aligned} \sum_{j=0}^h \frac{v_{i,t+j} - v_{i,t-1}}{y_{i,t-1}} &= m_c^h \sum_{j=0}^h \frac{c_{i,t+j}^g - c_{i,t-1}^g}{y_{i,t-1}} + m_x^h \sum_{j=0}^h \frac{x_{i,t+j}^g - x_{i,t-1}^g}{y_{i,t-1}} \\ &+ \text{controls} + \gamma_i^h + \delta_t^h + \tau_i^h t + \varepsilon_{i,t+h}^v, \quad h = 0, \dots, H. \end{aligned} \quad (24)$$

where m_c^h and m_x^h are the multipliers for government consumption and investment, respectively. Note that these multipliers are *cumulative*, which contrasts to alternative definitions occasionally used in the literature. The definition used here is both consistent with the model and favored by recent work. When I estimate this specification, I use the shocks $\hat{u}_{i,t}^c$ and $\hat{u}_{i,t}^x$ as instruments for the cumulative government spending variables. Because the sample is relatively short, I calculate impulse response functions and multipliers up to a time horizon of two years ($H = 7$). Note that in specifications (23) and (24) all coefficients are specific to the left hand side variable v . I omit this dependence for notational clarity.

¹⁴For the impulse response functions, this two-step procedure is numerically equivalent to regressing the left hand side of (23) on the actual changes in purchases and the forecasts of purchases in the two sectors (as in equation 22) in addition to the other control variables.

Throughout the analysis, I use Driscoll and Kraay (1998) standard errors which allow for arbitrary autocorrelation and cross-sectional correlation of the regression error. Coibion and Gorodnichenko (2012) show that a two-step analysis such as this does not invalidate the standard errors.

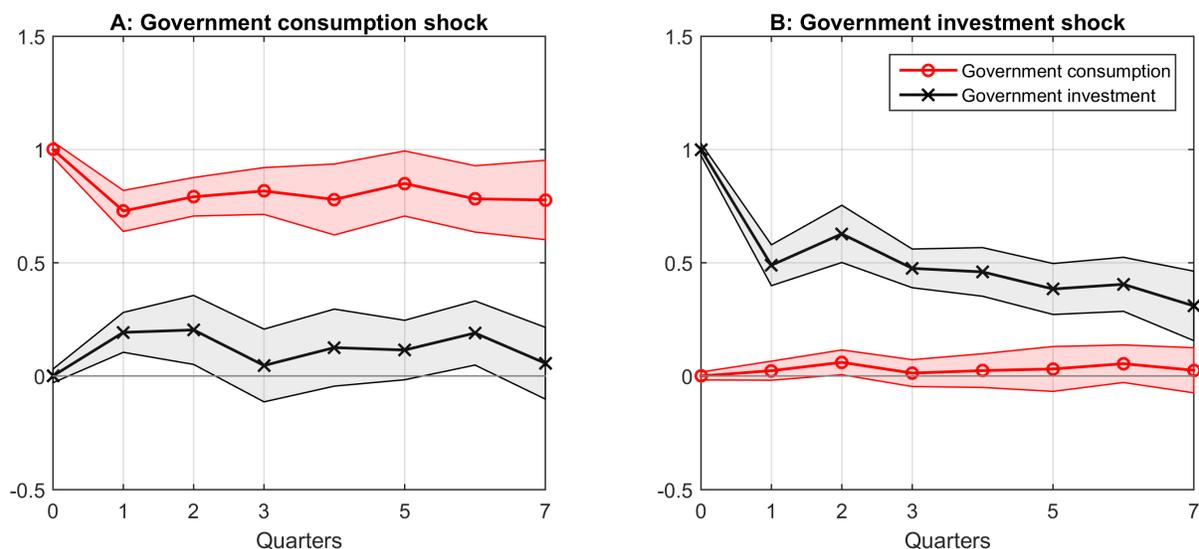
3.3 Baseline results

I begin with estimates for the full sample which includes episodes at and away from the zero lower bound on nominal interest rates. I will present separate estimates below. Figure 4 shows the impulse response functions of government consumption and investment. The government consumption shock leads to persistently elevated levels of government consumption for all 8 quarters. Government investment responds largely insignificantly to a government consumption shock. The government investment shock raises government investment which then decays gradually to about one third after 8 quarters. This corresponds to a half-life of 4 to 5 quarters. As Figure 3 illustrated, the model predicts that this configuration of shock persistence should lead to large differences between the government consumption and investment multiplier. Government consumption virtually remains unchanged after a government investment shock.¹⁵

Figure 5 shows the impulse response functions of GDP, private consumption, and private investment. In response to a government consumption shock, GDP rises above zero and becomes statistically significant in the second quarter (Panel A). In contrast GDP remains indistinguishable from zero at all horizons after a government investment shock (Panel D). Panels B and E demonstrate that private consumption remains roughly unchanged after both shocks. At no horizon is the response significant at the 10 percent level. Finally, Panels C and F show the response of private investment. After a government investment shock, private investment falls significantly below zero—without a lag. The estimates become insignificant in the fourth quarter, but remain more than one standard error below zero until the eighth quarter. Private investment also falls in response to a government consumption shock, but then becomes positive. When comparing the two impulse response functions of private investment, it is important to keep in mind that the cumulative government investment response is smaller than the cumulative government consumption response. Despite that, the impulse response function of private investment is more negative after a government investment shock at all time horizons.

¹⁵Perotti (2004) uses an alternative identification scheme which leads to significant responses of government consumption to government investment shocks for some countries.

Figure 4: Impulse response functions of government purchases

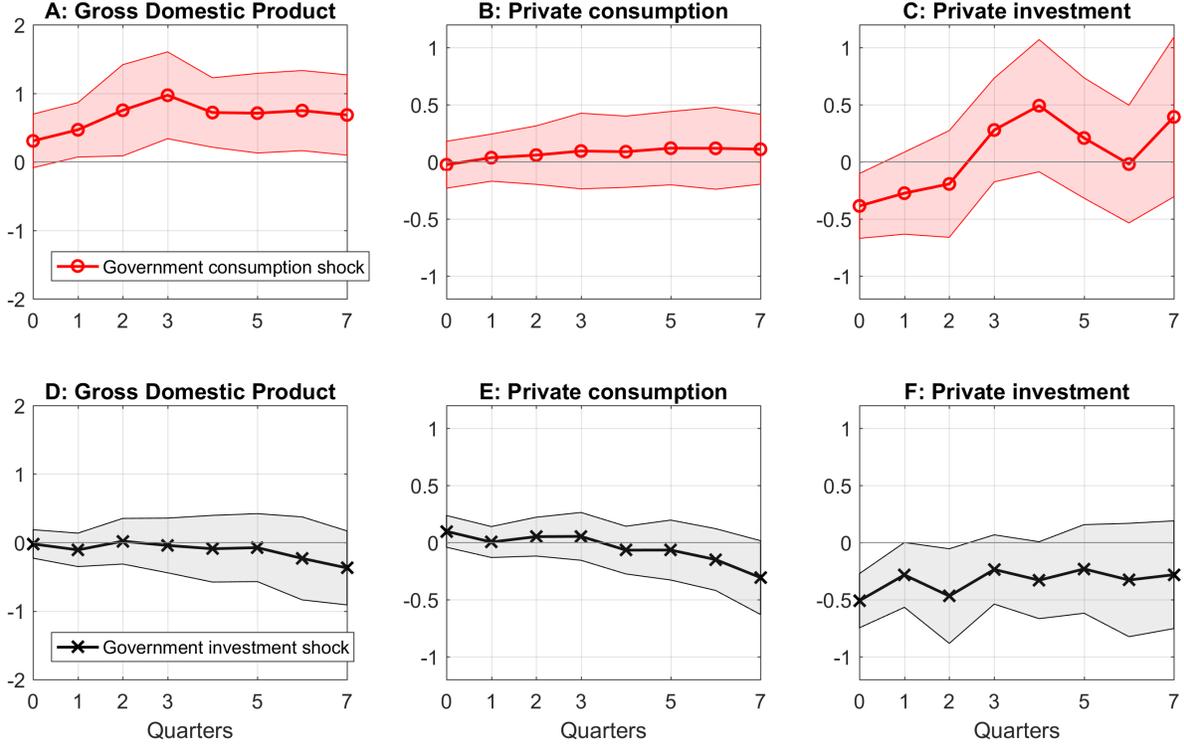


Notes: These estimates are based on specification (23). The shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

Table 3 presents the associated multipliers. GDP rises approximately 80 cents per dollar spent on government consumption goods. There is no measurable effect of government investment on GDP. The data rejects the hypothesis of equal GDP multipliers at a 4 quarter horizon with a p-value of 0.0628 and at a 8 quarter horizon with a p-value of 0.0630. Private consumption is neither crowded in nor out after either of the two shocks. However, private investment falls by 56 cents per dollar spent on investment goods after 4 quarters and by 66 cents after 8 quarters. The 4 quarter multiplier is significantly different from zero at the 5 percent level and the 8 quarter multiplier at the 10 percent level. The fact that private investment falls, rules out that the difference between the government consumption and investment multiplier is driven by greater measurement error of government investment. Note that the first stage F-statistics, calculated as suggested by Angrist and Pischke (2009, pp. 217-18) are far above 10.¹⁶

¹⁶In the presence of heteroskedasticity, autocorrelation, and clustering the conventional threshold of 10 does not generally apply. Olea and Pflueger (2013) develop a correction of the critical value which can be as high as 23.1 to bound the bias, still far below the F-statistics here. Further, the alternative test by Sanderson and Windmeijer (2016) rejects the null hypothesis of underidentification with p-values below 0.0001 for both endogenous regressors.

Figure 5: Impulse response functions of GDP, consumption, and investment



Notes: These estimates are based on specification (23). The shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

3.4 Prices and real interest rates

The model predicts that prices and real interest rates increase in response to government spending shocks (see Appendix A.6). In particular, it is the rise in own real interest rates which crowds out private sector spending. To test this prediction in the data, I estimate impulse response functions analogous to equation (23) but replace the left hand side with the percent change in prices $(p_{i,t+h}^s - p_{i,t-1}^s) / p_{i,t-1}^s$ or the absolute change in the real interest rate $r_{i,t+h}^s - r_{i,t-1}^s$, $s \in \{c, x\}$. The controls include the baseline controls as well as four lags of the change in the price p or r , respectively.

I construct the real interest rates in the two sectors from the Fisher relationship using a measure for the short-term nominal interest rate and the OECD's real-time forecasts for prices in the two sectors. While these real interest rates are direct empirical analogues for the model, it is clear that they will imperfectly measure the actual (or opportunity) cost of funds of investing firms. As a result, the estimates should be interpreted with caution. Because standard models

Table 3: Estimated government consumption and investment multipliers

LHS variable	Government consumption		Government investment		p-value of difference [†]	
	4	8	4	8	4	8
Gross domestic product	0.75** (0.34)	0.82** (0.34)	-0.06 (0.21)	-0.03 (0.34)	0.063	0.063
Private consumption	0.05 (0.18)	0.12 (0.23)	0.06 (0.13)	-0.10 (0.23)	0.954	0.553
Private investment	-0.12 (0.22)	0.17 (0.29)	-0.56** (0.23)	-0.66* (0.35)	0.126	0.103
First stage F-statistic	160.2	66.4	137.9	61.0		
Observations	762	697	762	697		

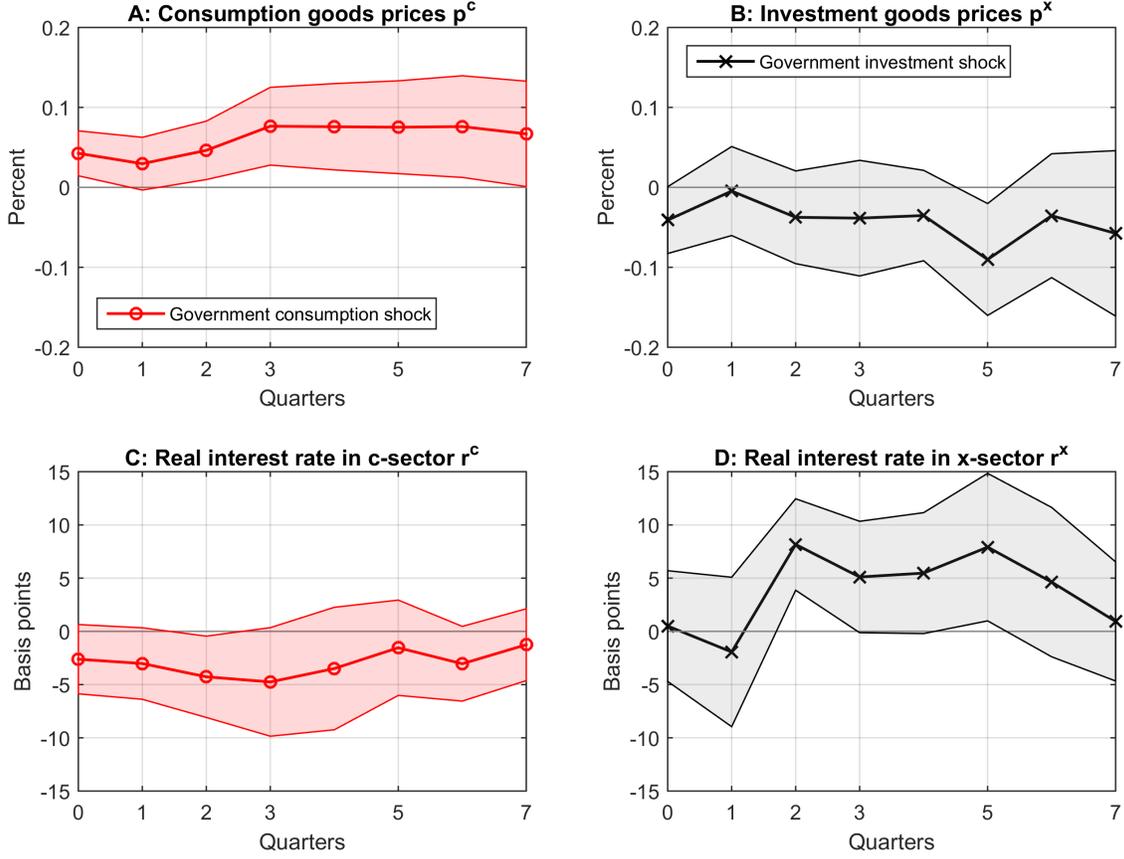
Notes: The estimates are based on specification (24). Driscoll-Kraay standard errors are reported in parentheses. ** and * denote significance at the 5 and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

predict that real interest rates behave differently at and away from the zero lower bound (ZLB) on nominal interest rates, I restrict the sample to observations at which the nominal interest rate is unconstrained.

Figure 6 shows the estimated impulse response functions. The responses are scaled to reflect a one standard deviation shock to the two measures of spending in the data. The price level of the consumption goods sector rises significantly, consistent with the model's predictions. Prices in the investment goods sector respond largely insignificantly (Panel B). Since the model predicts very small increases in investment prices, this evidence is *not* at odds with the theory. However, the model also predicts that the own real interest rate in the consumption goods sector should increase after a government consumption shock. There is little evidence for this prediction — the real interest rate in the consumption goods sector falls insignificantly below zero after the shock (Panel C). Finally, the real interest rate in the investment goods sector rises after a government investment shock. The magnitude of this increase is somewhat larger than predicted by the model (see Appendix A.6), although the large standard errors make a conclusive comparison difficult. Broadly, this evidence is consistent with the prediction that an elevated real interest rate crowds out private investment.

Figure 6: Impulse response functions of prices and real interest rates



Notes: The impulse response functions are estimated based on equation (23) after replacing the left hand side with the percent change in prices $(p_{i,t+h}^s - p_{i,t-1}^s) / p_{i,t-1}^s$ and the absolute change in the real interest rate $r_{i,t+h}^s - r_{i,t-1}^s$, $s \in \{c, x\}$. The controls include the baseline controls as well as four lags of the change in the price p or r , respectively. The sample is limited to observations away from the zero lower bound and the impulse response functions are scaled to reflect a one standard deviation change in the respective measure of spending. Shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

3.5 Extensions and robustness

I next present a number of extensions and robustness checks.

3.5.1 Government revenues

One concern is that government investment is more likely debt-financed than government consumption. In the presence of distortionary taxes and/or non-Ricardian consumers, this difference in financing could explain the different estimates of the two multipliers. To explore this possibility, I estimate the impulse response function for government revenues. The estimates, reported

Table 4: Robustness: Drop Great Recession

LHS variable	Government consumption		Government investment		p-value of difference [†]	
	4	8	4	8	4	8
Gross domestic product	0.98*** (0.29)	1.15*** (0.34)	-0.53** (0.25)	-1.13*** (0.42)	0.001	0.000
Private consumption	0.14 (0.21)	0.23 (0.24)	-0.06 (0.14)	-0.50** (0.24)	0.466	0.066
Private investment	0.06 (0.27)	0.22 (0.32)	-0.56*** (0.21)	-1.23*** (0.47)	0.090	0.032
First stage F-statistic	111.2	31.3	130.0	33.4		
Observations	573	512	573	512		

Notes: The estimates are based on specification (24). The sample excludes the years 2008 to 2010. Driscoll-Kraay standard errors are reported in parentheses. ** and * denote significance at the 5 and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

in Appendix C Figure C2, show that revenues rise moderately for 3 quarters after a government consumption shock and then return to zero. In contrast, revenues fall gradually after a government investment shock. Since higher revenues should be associated with contractionary effects on output the behavior of revenues cannot explain the relatively large government consumption and the relatively small government investment multipliers. Standard models would predict that the difference should be larger under identical financing schemes.

3.5.2 Dropping the Great Recession

During the Great Recession a number of countries passed fiscal stimulus packages to combat the economic contraction. In some cases (such as the U.S.) these programs were passed fairly quickly which is potentially inconsistent with the identification assumption that the government does not respond to changes in economic conditions within the same quarter. If so, one would expect that the coefficients are biased downwards when including this episode. Table 4 reports estimates when the Great Recession years 2008 to 2010 are dropped from the sample.

Without the Great Recession years, the GDP multiplier for government consumption is indeed slightly larger and around unity. However, the GDP multiplier for government investment is now smaller than before and significantly negative. Investment falls by 56 cents on the dollar

after 4 quarters and more than one for one after 8 quarters. Further, private consumption falls significantly 8 quarters after an increase in government investment. While the baseline results are more consistent with the model, it is clear that the small multipliers for government investment are not driven by the Great Recession episode. Note that the F-statistics remain far above conventional threshold levels.

3.5.3 Additional robustness

I perform two additional robustness tests. First, Figure C3 in Appendix C presents estimates of the private investment multiplier after government investment shocks, dropping one country at a time. The estimate of the government investment multiplier is significantly negative in all cases. Thus, private investment is robustly crowded out after government investment shocks.

Second, I estimate multipliers using the standard Blanchard-Perotti identification scheme (i.e. without using forecasts to purify the spending shocks). The advantage of not requiring forecasts is that the sample size more than doubles and I can estimate multipliers at longer horizons with reasonable precision. On the other hand, the estimates are potentially biased downwards (Ramey, 2009). The results are reported in Appendix Table C1. Similar to the benchmark estimates, the government consumption multiplier is around 0.8 for the first 8 quarters and the investment multiplier indistinguishable from zero. Further, the government investment multiplier remains very close to zero for horizons up to 20 quarters while the government consumption multiplier rises above unity (although not significantly so).

3.5.4 The zero lower bound

New Keynesian models typically behave discontinuously at a nominal interest rate of zero (Christiano, Eichenbaum, and Rebelo, 2011, Woodford, 2011, and others). Further, some of these models predict that government purchases are far more effective when monetary policy is constrained by the zero lower bound. Given these predictions, it is potentially incorrect to estimate a single multiplier for the entire sample period which includes episodes at and away from the ZLB. Table 5 reports separate estimates. When constructing the samples I assume that an economy is at the ZLB when the short-term nominal interest rate is below 0.75, see Appendix B for details.

When I restrict the sample to episodes away from the ZLB (Panel A), the estimated multipliers are very similar to those in the baseline (Table 3). The GDP multiplier remains much larger

Table 5: Robustness: The Zero Lower Bound

Panel A: Away from ZLB						
LHS variable	Government consumption		Government investment		p-value of difference†	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	0.65 (0.41)	0.68* (0.37)	0.00 (0.24)	0.27 (0.31)	0.175	0.375
Private consumption	-0.10 (0.18)	-0.07 (0.20)	0.07 (0.14)	0.06 (0.22)	0.529	0.720
Private investment	-0.29 (0.29)	0.06 (0.29)	-0.59** (0.26)	-0.49 (0.38)	0.357	0.289
First stage F-statistic	89.4	27.7	98.2	45.3		
Observations	523	502	523	502		

Panel B: At ZLB						
LHS variable	Government consumption		Government investment		p-value of difference†	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	1.41*** (0.37)	1.59*** (0.42)	1.31* (0.73)	0.25 (0.94)	0.906	0.229
Private consumption	0.22 (0.34)	0.56 (0.44)	0.78** (0.36)	0.34 (0.68)	0.335	0.800
Private investment	0.49 (0.34)	1.15** (0.52)	-0.47 (0.38)	-1.79*** (0.45)	0.077	0.000
First stage F-statistic	30.4	11.7	15.8	7.0		
Observations	239	195	239	195		

Panel C: p-values (H0: Multipliers at and away from the ZLB are equal)						
	Government consumption		Government investment			
	4 quarters	8 quarters	4 quarters	8 quarters		
Gross domestic product	0.225	0.097	0.100	0.991		
Private consumption	0.437	0.210	0.071	0.699		
Private investment	0.087	0.033	0.800	0.017		

Notes: The estimates are based on specification (24) with a restricted sample. Away from ZLB uses observations with short-term interest rates above 0.75, and At the ZLB uses observations with short-term interest rates below 0.75. Driscoll-Kraay standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

when the government consumes than when it invests. Further, government investment crowds out private investment, and significantly so at a 4 quarter horizon. Private consumption responds very little.

At the ZLB, however, the estimates are different (Panel B). GDP rises by approximately 1.5 dollars per dollar spent on the government consumption good. The rise in GDP is attributable in part to consumption, which rises insignificantly, and to investment, which rises significantly after 8 quarters. The GDP multiplier for government investment is 1.3 after 4 quarters, but then drops to 0.25 after 8 quarters. Somewhat surprisingly, the value above one reflects a significant rise in consumption. Private investment is always crowded out. Note that the null of equal multipliers at and away from the ZLB can be rejected in some instances (Panel C).

Two caveats are in place when interpreting these results. First, the sample is now significantly smaller with approximately 200 observations. Second, the first stage F-statistics are smaller. In the case of government investment it falls below 10 at the 8 quarter horizon, suggesting that the estimates could be unreliable and biased.

Broadly, these findings are consistent with Miyamoto, Nguyen, and Sergeyev (2017), although they do not estimate separate multipliers for government consumption and investment. There is also some evidence that prices increase in the consumption goods sector after a government consumption shock when the economy is at the ZLB. Investment prices show no clear pattern after government investment shocks (see Figure C4 in Appendix C).

3.5.5 The state of the business cycle

I lastly explore the possibility that fiscal multipliers depend on the state of the business cycle (Auerbach and Gorodnichenko, 2012, 2013). Before proceeding, I note that the results I report below depend on how I measure the state of the business cycle. Reflecting the disagreement in the literature, alternative measures of slack yield different results.¹⁷

As a benchmark I measure the state of the business cycle as in Ramey and Zubairy (2017). That is, I use an indicator function which takes the value one if the unemployment rate is above the country-specific median. I call this measure $\text{slack}_{i,t}$. The identification proceeds analogous to the 2-step procedure described in Section 3.2. To allow for state-dependent responses to shocks, I now interact all variables with $\text{slack}_{i,t}$ and $1 - \text{slack}_{i,t}$ prior to estimating specifications (22), (23), and (24). I also add a main effect of $\text{slack}_{i,t}$ to the control variables.

¹⁷Boehm and Pandalai-Nayar (2018) develop a model to motivate capacity utilization as a measure of slack.

Table 6: State-dependent multipliers

Panel A: High unemployment state ($\text{slack}_{i,t} = 1$)						
LHS variable	Government consumption		Government investment		p-value of difference†	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	0.93** (0.39)	1.29** (0.60)	-0.52 (0.34)	-0.80* (0.44)	0.005	0.011
Private consumption	0.06 (0.18)	0.42 (0.30)	-0.18 (0.16)	-0.50 (0.31)	0.366	0.054
Private investment	-0.05 (0.30)	0.54 (0.56)	-0.79** (0.35)	-1.62*** (0.51)	0.132	0.019
First stage F-statistic	30.4	20.8	33.1	22.5		
Observations	762	697	762	697		

Panel B: Low unemployment state ($\text{slack}_{i,t} = 0$)						
LHS variable	Government consumption		Government investment		p-value of difference†	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	0.63 (0.54)	0.66 (0.43)	0.20 (0.28)	0.13 (0.44)	0.471	0.379
Private consumption	0.01 (0.29)	-0.09 (0.35)	0.14 (0.19)	-0.04 (0.30)	0.735	0.921
Private investment	-0.36 (0.33)	-0.23 (0.35)	-0.48 (0.31)	-0.50 (0.41)	0.734	0.617
First stage F-statistic	41.9	26.1	52.7	16.0		
Observations	762	697	762	697		

Panel C: p-value (H_0 : Equal multipliers over the business cycle)				
	Government consumption		Government investment	
	4 quarters	8 quarters	4 quarters	8 quarters
Gross domestic product	0.666	0.430	0.099	0.105
Private consumption	0.873	0.290	0.114	0.162
Private investment	0.501	0.304	0.518	0.055

Notes: Estimates are obtained as described in Section 3.5.5. Driscoll-Kraay standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

The point estimates suggest a modest degree of state dependence in both multipliers (Table 6). The government consumption multiplier is slightly larger during slumps, but I cannot reject the null hypothesis of equal consumption multipliers over the business cycle. The government investment multiplier is smaller in episodes of slack, and this difference is marginally significant ($p \approx 0.10$). Further, the drop in private investment is striking during slumps. Although these

findings are similar to Berger and Vavra (2014), I again caution that these estimates are dependent on how the state of the business cycle is measured. I report estimates for an alternative measure of slack in Appendix C.2.

4 External validity of multipliers for total purchases

In this section I discuss the implications of my findings for estimated multipliers for total government purchases. I show that this multiplier can suffer from external validity problems.

4.1 A decomposition

I begin with presenting an identity which relates the multiplier for total purchases to the government consumption and investment multipliers. In what follows variables without subscripts are vectors or matrices of stacked variables with subscripts. For instance, y is the vector of stacked $y_{i,t}$, Q is the matrix of stacked $q'_{i,t}$, and so forth.

Proposition 4.1. *Consider the three models*

$$y_{i,t} = mg_{i,t} + q'_{i,t}\beta_g + \varepsilon^g_{i,t}, \quad (25)$$

$$y_{i,t} = m_x x^g_{i,t} + q'_{i,t}\beta_x + \varepsilon^x_{i,t}, \quad (26)$$

$$y_{i,t} = m_c c^g_{i,t} + q'_{i,t}\beta_c + \varepsilon^c_{i,t}, \quad (27)$$

where $y_{i,t}$ is a common left hand side variable, $q_{i,t}$ a common vector of control variables, and

$$g_{i,t} = x^g_{i,t} + c^g_{i,t}. \quad (28)$$

There are instruments $z^g_{i,t}$ for $g_{i,t}$, $z^x_{i,t}$ for $x^g_{i,t}$, and $z^c_{i,t}$ for $c^g_{i,t}$, such that

$$z^g_{i,t} = z^x_{i,t} + z^c_{i,t}. \quad (29)$$

Then the exactly identified instrumental variable (IV) estimators satisfy

$$\hat{m}_g = \omega_x \hat{m}_x + \omega_c \hat{m}_c, \quad (30)$$

where

$$\omega_x = \frac{(M_Q z^x)' M_Q x^g}{(M_Q z^g)' M_Q g}, \quad \omega_c = \frac{(M_Q z^c)' M_Q c^g}{(M_Q z^g)' M_Q g}, \quad (31)$$

and $M_Q = I - Q(Q'Q)^{-1}Q'$.

Proof. See Appendix D. □

When applied to the question at hand, the proposition states that multiplier estimates for total purchases are weighted averages of the estimates for government consumption and investment (equation 30).

The weights ω_x and ω_c capture the *fraction of the identifying variation due to government investment and consumption*. More precisely, the weight ω_x is the covariance between the instrument $z_{i,t}^x$ and the spending variable $x_{i,t}^g$ divided by the covariance between the instrument for total purchases $z_{i,t}^g$ with total purchases $g_{i,t}$. Both covariances are calculated after residualizing with respect to the control variables. This is what the matrix M_Q does.

I add two remarks. First, the proposition requires no assumption on the true underlying model but relates the estimates of the three different multipliers under any data generating process. This implies that if the conditions of the proposition were satisfied, then equation (30) would hold exactly in the data. Second, the weights ω_x and ω_c do not in general sum to one. If the instrument for government investment (z^x) is correlated with government consumption (c^g) (and vice versa), after controlling for other factors, then $\omega_x + \omega_c \neq 1$. I discuss details in Appendix D.

In practice, the assumptions of Proposition 4.1 do not hold exactly. First, chained indexes are not additive, so that equation (28) does not hold due to statistical discrepancy (see Whelan, 2000). Second, I prefer to estimate the government consumption multiplier while controlling for government investment shocks and the government investment multiplier while controlling for government consumption shocks. In other words, I add an additional control to equations (26) and (27). As I established in Section 3, these controls have only small effects on the estimates, but break the identity in equation (30).

4.2 Multiplier estimates for total purchases

Panel A of Table 7 shows the estimate of the multiplier for total purchases and compares them to the estimates for government consumption and investment which are restated here for convenience. I estimate the multiplier for total purchases based on equation (24), using $z^g = \hat{u}^c + \hat{u}^x$ as the

Table 7: Comparison of multiplier estimates

Panel A: Multiplier estimates						
Horizon (quarters)	Government consumption		Government investment		Total purchases	
	4	8	4	8	4	8
Gross Domestic Product	0.75** (0.34)	0.82** (0.34)	-0.06 (0.21)	-0.03 (0.34)	0.25 (0.18)	0.35 (0.28)
First stage F-statistic	160.2	66.4	137.9	61.0	282.3	200.8
Observations	762	697	762	697	762	697

Panel B: Multipliers constructed from approximation (30)						
Horizon (quarters)	ω_c		ω_x		Total purchases	
	4	8	4	8	4	8
Weights	0.320	0.364	0.589	0.538		
Gross Domestic Product					0.20	0.28

Notes: The estimates in Panel A are based on specification (24) as described in the text. Panel B reports the weights as stated in (31) and constructs the multiplier for total purchases from the government consumption and investment multipliers as reported in Panel A, using approximation (30). Driscoll-Kraay standard errors are reported in parentheses. ** denotes significance at the 5 percent level.

instrument. The estimate is surprisingly small with a value of approximately 0.25 after 4 quarters and 0.35 after 8 quarters. At neither horizon is the estimate significantly different from zero.

The fact that the multiplier estimate for total purchases is small and closer to the estimate for government investment can be understood using the decomposition introduced above (equation 30). Although government investment constitutes a much smaller fraction of GDP than government consumption (on average, 3 versus 19 percent), it is more volatile. In my sample, the standard deviation of $(x_{i,t}^g - x_{i,t-1}^g)/y_{i,t-1}$ is 0.0025 while the standard deviation of $(c_{i,t}^g - c_{i,t-1}^g)/y_{i,t-1}$ is 0.0016. This implies that a larger share of the identifying variation comes from government investment shocks so that ω_x is greater than ω_c . Panel B of Table 7 reports these weights (constructed from 31). At a 4 quarter horizon ω_x is 0.589 while ω_c is 0.320. At an 8 quarter horizon $\omega_x = 0.538$ and $\omega_c = .364$. Hence, the majority of the variation of total purchases is driven by government investment. This renders the associated multiplier estimate small.

When I compute the multiplier for total purchases from equation (30), using the estimates and weights as reported in Table 7, I obtain a multiplier of 0.2 after 4 quarters and a multiplier of 0.35 after 8 quarters. As noted before, these values differ slightly from the estimates in Panel A since relationship (30) holds only approximately (see Appendix Table D1 for details).

Since the estimated multipliers for total purchases in Table 7 are small in comparison to the literature, I also report results from a standard Blanchard-Perotti identification scheme (i.e. without purifying changes in purchases of their anticipated components) in Appendix C Table C2. The multiplier for total purchases is now slightly larger and 0.37 (0.38) after 4 (8) quarters. The weights ω_x and ω_c are roughly equal in this sample.

4.3 External validity

If government consumption and government investment are associated with different spending multipliers, the econometric model for total purchases is misspecified. This misspecification has the potentially important implication that a change in the composition of government purchases affects the multiplier—even if the underlying multipliers for government consumption and investment remain the same. As a result, such compositional changes lead to an external validity problem for multipliers which are estimated from variation in total purchases.

In practice, this external validity problem appears in various forms. First and most importantly, if actual stimulus programs have a different composition of spending than the variation underlying the estimation, then the estimated multiplier for total purchases will not provide accurate guidance for policy.¹⁸ Second, it is likely that alternate samples and identification schemes rely on different compositions of variation in government consumption and investment. To the extent that this is the case, one would not expect to find the same multiplier across identification schemes. Third, even for a given sample and a given identification scheme, the estimated multipliers at different time horizons are not generally comparable. Since government consumption shocks are more persistent than government investment shocks in my sample, the identifying variation at short time horizons is different from the identifying variation at longer horizons. As Panel B of Table 7 shows, the weight shifts towards government consumption at the 8 quarter horizon (by approximately 5 percentage points). It follows that the point estimate at 8 quarters is

¹⁸Unfortunately, data on the precise composition of spending is to my knowledge not available. For the American Recovery and Reinvestment Act, such data principally exists at www.usaspending.gov. However, the large majority of spending came in the form of grants without precise industry identifiers. This makes an empirical assessment difficult.

greater than that at 4 quarters in part due to the relatively greater importance of the government consumption shock. Although the magnitude is not large, this example highlights that comparing multipliers for total purchases is prone to problems.¹⁹

5 Conclusion

A standard two sector model predicts that the government investment multiplier is much smaller than the government consumption multiplier. I offer two equivalent explanations for this result. The first explanation highlights that government investment has essentially no wealth effect on household's labor supply. The second explanation emphasizes that due to greater intertemporal substitutability, private investment contracts more after government investment shocks than private consumption after government consumption shocks. Given that prior work has placed significant emphasis on both the wealth effect and the crowding out of private investment these findings suggest that researchers should—if the data permit—open the black box of government purchases and separate it into government consumption and government investment. If the composition of purchases matters, multiplier estimates for total purchases suffer from an external validity problem. Once the composition of purchases changes, the multiplier changes as well.

I test the model's predictions in a panel of OECD countries and obtain results broadly consistent with the model's predictions. First, the output multiplier for government consumption shocks exceeds the multiplier for government investment shocks. Second, this difference is driven in large part by the contraction in private investment after public investment shocks. Third, there is evidence of an increase in the own real interest rate in the investment goods sector. This evidence is based on state-of-the-art methodology which relies on quarterly data and purges spending shocks of their anticipated components.

These results raise concerns about the effectiveness of fiscal stimulus that is targeted towards infrastructure. As many other stimulus programs, the American Recovery and Reinvestment Act contained provisions to raise spending on highly durable goods such as highway infrastructure, high-speed rail corridors, railroads, airports, and broadband. Further, it has been suggested to assemble a pool of “shovel-ready” investment projects—to be implemented when the economy

¹⁹While the “portability” of the government consumption and investment multipliers is likely better than that of the multiplier for total purchases, this external validity comes at a cost. Since total purchases exhibits greater variation than the two components alone, the multiplier for total purchases is estimated with greater precision (see Panel A of Table 7).

next plunges into recession. This initiative could potentially overcome the main hurdle for using government investment as a tool for stabilization policy. The findings in this paper suggest that it may be desirable to focus on government consumption instead since such stimulus is likely more effective.

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A Model appendix

For this Appendix, I define the following constants

$$\begin{aligned} s_y^x &:= \frac{p^x x}{p^x x + p^c c} = \left(\frac{n^x}{n} \right)^{\frac{\eta+\mu}{\eta}} = \frac{\alpha \delta}{(1 - s_x^g)(\beta^{-1} - 1 + \delta)} \\ s_x^x &:= \frac{x^x}{x} = \frac{\alpha \delta}{\beta^{-1} - 1 + \delta} \\ s_x^c &:= \frac{x^c}{x} = 1 - s_x^g - \frac{\alpha \delta}{\beta^{-1} - 1 + \delta} \end{aligned}$$

A.1 Summary of model equations

Labor supply decisions

$$\begin{aligned} \phi(n_t)^{\frac{1}{\eta} - \frac{\mu}{\eta}} (n_t^x)^{\frac{\mu}{\eta}} &= (c_t^h)^{-\frac{1}{\sigma}} \frac{p_t^x w_t^x}{p_t^c p_t^x} \\ \phi(n_t)^{\frac{1}{\eta} - \frac{\mu}{\eta}} (n_t^c)^{\frac{\mu}{\eta}} &= (c_t^h)^{-\frac{1}{\sigma}} \frac{w_t^c}{p_t^c} \end{aligned}$$

Euler equation for nominal bond

$$(c_t^h)^{-\frac{1}{\sigma}} = \beta(1 + i_t) E_t \left[\frac{1}{1 + \pi_{t+1}^c} (c_{t+1}^h)^{-\frac{1}{\sigma}} \right]$$

Labor aggregator

$$n_t = \left[(n_t^c)^{\frac{\eta+\mu}{\eta}} + (n_t^x)^{\frac{\eta+\mu}{\eta}} \right]^{\frac{\eta}{\eta+\mu}}$$

Investment choice

$$\begin{aligned} 1 &= \frac{\gamma_t^c}{p_t^c} \vartheta' \left(\frac{x_t^c}{k_t^c} \right) \\ 1 &= \frac{\gamma_t^x}{p_t^x} \vartheta' \left(\frac{x_t^x}{k_t^x} \right) \end{aligned}$$

Euler equations for capital

$$\begin{aligned} \frac{\gamma_t^c}{p_t^c} &= E_t \left[\frac{1}{1 + i_t} \frac{p_{t+1}^x}{p_t^x} \left(\frac{r_{k,t+1}^c}{p_{t+1}^c} + \frac{\gamma_{t+1}^c}{p_{t+1}^c} \left((1 - \delta) + \vartheta \left(\frac{x_{t+1}^c}{k_{t+1}^c} \right) - \vartheta' \left(\frac{x_{t+1}^c}{k_{t+1}^c} \right) \frac{x_{t+1}^c}{k_{t+1}^c} \right) \right) \right] \\ \frac{\gamma_t^x}{p_t^x} &= E_t \left[\frac{1}{1 + i_t} \frac{p_{t+1}^x}{p_t^x} \left(\frac{r_{k,t+1}^x}{p_{t+1}^x} + \frac{\gamma_{t+1}^x}{p_{t+1}^x} \left((1 - \delta) + \vartheta \left(\frac{x_{t+1}^x}{k_{t+1}^x} \right) - \vartheta' \left(\frac{x_{t+1}^x}{k_{t+1}^x} \right) \frac{x_{t+1}^x}{k_{t+1}^x} \right) \right) \right] \end{aligned}$$

Capital accumulation equations

$$\begin{aligned} k_{t+1}^x &= k_t^x (1 - \delta) + \vartheta \left(\frac{x_t^x}{k_t^x} \right) k_t^x \\ k_{t+1}^c &= k_t^c (1 - \delta) + \vartheta \left(\frac{x_t^c}{k_t^c} \right) k_t^c \end{aligned}$$

Phillips curves (tildes denote percent deviations from steady state, linear approximations)

$$\begin{aligned}\pi_t^x &= \frac{(1-\theta_x)(1-\theta_x\beta)}{\theta_x} \frac{\widetilde{mc}_t^x}{p_t^x} + \beta E_t [\pi_{t+1}^x] \\ \pi_t^c &= \frac{(1-\theta_c)(1-\theta_c\beta)}{\theta_c} \frac{\widetilde{mc}_t^c}{p_t^c} + \beta E_t [\pi_{t+1}^c]\end{aligned}$$

Factor demands

$$\begin{aligned}\frac{w_t^c}{p_t^c} &= \frac{mc_t^c}{p_t^c} (1-\alpha) (k_t^c)^\alpha (n_t^c)^{-\alpha} \\ \frac{r_{k,t}^c}{p_t^c} &= \frac{mc_t^c}{p_t^c} \alpha (k_t^c)^{\alpha-1} (n_t^c)^{1-\alpha} \\ \frac{w_t^x}{p_t^x} &= \frac{mc_t^x}{p_t^x} (1-\alpha) (k_t^x)^\alpha (n_t^x)^{-\alpha} \\ \frac{r_{k,t}^x}{p_t^x} &= \frac{mc_t^x}{p_t^x} \alpha (k_t^x)^{\alpha-1} (n_t^x)^{1-\alpha}\end{aligned}$$

Production functions

$$\begin{aligned}x_t &= (k_t^x)^\alpha (n_t^x)^{1-\alpha} \\ c_t &= (k_t^c)^\alpha (n_t^c)^{1-\alpha}\end{aligned}$$

Market clearing conditions

$$\begin{aligned}x_t &= x_t^x + x_t^c + x_t^g \\ c_t &= c_t^h + c_t^g\end{aligned}$$

Fisher equations

$$\begin{aligned}1+i_t &= (1+r_t^x) E_t [1+\pi_{t+1}^x] \\ 1+i_t &= (1+r_t^c) E_t [1+\pi_{t+1}^c]\end{aligned}$$

Evolution of relative prices

$$\frac{\frac{p_t^x}{p_{t-1}^x}}{\frac{p_t^c}{p_{t-1}^c}} = \frac{\pi_t^x}{\pi_t^c}$$

Taylor rule (d denotes absolute deviations from steady state)

$$\begin{aligned}di_t &= \phi_\pi \pi_t \quad \text{in baseline calibration} \\ di_t &= \phi_\pi \pi_t^c \quad \text{in non-symmetric calibration}\end{aligned}$$

Real GDP

$$y_t = p^x x_t + p^c c_t$$

Deflator inflation

$$\pi_t = s_y^x \pi_t^x + (1-s_y^x) \pi_t^c$$

Shock processes

$$\begin{aligned}x_t^g &= (1 - \varrho_x^g) x_t^g + \varrho_x^g x_{t-1}^g + \varepsilon_{x,t}^g \\c_t^g &= (1 - \varrho_c^g) c_t^g + \varrho_c^g c_{t-1}^g + \varepsilon_{c,t}^g\end{aligned}$$

This is a total of 28 equations. To solve the model, I linearize around the non-stochastic steady state and solve the model with a version of the Anderson-Moore algorithm.

A.2 Proofs

A.2.1 Proof of Proposition 2.1

Proposition. *Consider the model in Section 2.1 and suppose prices are flexible ($\theta_c = \theta_x = 0$). Suppose further that δ is arbitrarily close to zero. Then, for a short-lived increase in spending ($\varrho_x^g = \varrho_c^g = 0$),*

$$\begin{aligned}m_x &\approx 0, \\m_c &\approx \frac{(1 - \alpha) \left(\frac{\mu}{\eta} + \alpha \right)}{(1 - \alpha) \left(\frac{1 - \mu}{\eta} s_y^x + \frac{\mu}{\eta} + \alpha \right) + (1 - s_c^g) \sigma \left(\frac{\mu}{\eta} + \alpha \right) \left(\alpha + \frac{1}{\eta} \right)}.\end{aligned}$$

Proof. Letting tildes denote percent deviations from steady state, and d absolute deviations, the linearized equations for the flexible price model are:

Labor supply decisions

$$\begin{aligned}\frac{1 - \mu}{\eta} \tilde{n}_t + \frac{\mu}{\eta} \tilde{n}_t^x &= -\frac{1}{\sigma} \tilde{c}_t^h + \frac{\tilde{p}_t^x}{p_t^c} + \frac{\tilde{w}_t^x}{p_t^x} \\ \frac{1 - \mu}{\eta} \tilde{n}_t + \frac{\mu}{\eta} \tilde{n}_t^c &= -\frac{1}{\sigma} \tilde{c}_t^h + \frac{\tilde{w}_t^c}{p_t^c}\end{aligned}$$

Euler equation for nominal bond

$$-\frac{1}{\sigma} \tilde{c}_t^h = \beta \text{d}r_t^c - \frac{1}{\sigma} E_t [\tilde{c}_{t+1}^h]$$

Labor aggregator

$$\tilde{n}_t = (1 - s_y^x) \tilde{n}_t^c + s_y^x \tilde{n}_t^x$$

Investment choice

$$\frac{\tilde{\gamma}_t^x}{p_t^x} = \zeta \delta \tilde{x}_t^x - \zeta \delta \tilde{k}_t^x \tag{A1}$$

$$\frac{\tilde{\gamma}_t^c}{p_t^x} = \zeta \delta \tilde{x}_t^c - \zeta \delta \tilde{k}_t^c \tag{A2}$$

Euler equations for capital

$$\frac{\tilde{\gamma}_t^x}{p_t^x} + \beta \text{d}r_t^x = E_t \left[(1 - \beta(1 - \delta)) \frac{\tilde{r}_{k,t+1}^x}{p_{t+1}^x} + \beta(1 - \delta) \frac{\tilde{\gamma}_{t+1}^x}{p_{t+1}^x} + \beta \zeta \delta^2 (\tilde{x}_{t+1}^x - \tilde{k}_{t+1}^x) \right] \tag{A3}$$

$$\frac{\tilde{\gamma}_t^c}{p_t^x} + \beta \text{d}r_t^x = E_t \left[(1 - \beta(1 - \delta)) \left[\frac{\tilde{r}_{k,t+1}^c}{p_{t+1}^c} - \frac{\tilde{p}_{t+1}^x}{p_{t+1}^c} \right] + \beta(1 - \delta) \frac{\tilde{\gamma}_{t+1}^c}{p_{t+1}^x} + \beta \zeta \delta^2 (\tilde{x}_{t+1}^c - \tilde{k}_{t+1}^c) \right] \tag{A4}$$

Capital accumulation equations

$$\tilde{k}_{t+1}^x = (1 - \delta) \tilde{k}_t^x + \delta \tilde{x}_t^x \quad (\text{A5})$$

$$\tilde{k}_{t+1}^c = (1 - \delta) \tilde{k}_t^c + \delta \tilde{x}_t^c \quad (\text{A6})$$

Factor demands

$$\begin{aligned} \frac{\widetilde{w}_t^c}{\widetilde{p}_t^c} &= \alpha \tilde{k}_t^c - \alpha \tilde{n}_t^c \\ \frac{\widetilde{r}_{k,t}^c}{\widetilde{p}_t^c} &= -(1 - \alpha) \tilde{k}_t^c + (1 - \alpha) \tilde{n}_t^c \\ \frac{\widetilde{w}_t^x}{\widetilde{p}_t^x} &= \alpha \tilde{k}_t^x - \alpha \tilde{n}_t^x \\ \frac{\widetilde{r}_{k,t}^x}{\widetilde{p}_t^x} &= -(1 - \alpha) \tilde{k}_t^x + (1 - \alpha) \tilde{n}_t^x \end{aligned}$$

Production functions

$$\begin{aligned} \tilde{x}_t &= \alpha \tilde{k}_t^x + (1 - \alpha) \tilde{n}_t^x \\ \tilde{c}_t &= \alpha \tilde{k}_t^c + (1 - \alpha) \tilde{n}_t^c \end{aligned}$$

Market clearing conditions

$$\begin{aligned} \tilde{x}_t &= s_x^x \tilde{x}_t^x + s_x^c \tilde{x}_t^c + s_x^g \tilde{x}_t^g \\ \tilde{c}_t &= (1 - s_c^g) \tilde{c}_t^h + s_c^g \tilde{c}_t^g \end{aligned}$$

Fisher equations

$$\beta \text{d}r_t^x = \beta \text{d}r_t^c - E_t \left[\frac{\widetilde{p}_{t+1}^x}{\widetilde{p}_{t+1}^c} \right] + \frac{\widetilde{p}_t^x}{\widetilde{p}_t^c}$$

Real GDP

$$\tilde{y}_t = s_y^x \tilde{x}_t + (1 - s_y^x) \tilde{c}_t$$

Shock processes

$$\begin{aligned} \tilde{x}_t^g &= \varrho_x^g \tilde{x}_{t-1}^g + \varepsilon_{x,t}^g \\ \tilde{c}_t^g &= \varrho_c^g \tilde{c}_{t-1}^g + \varepsilon_{c,t}^g \end{aligned}$$

Now assume $\varrho_x^g = \varrho_c^g = 0$. Further note that the only other state variables are the capital stocks. If δ is close to zero, then the accumulation equations (A5 and A6) imply that

$$\tilde{k}_{t+1}^x \approx \tilde{k}_t^x \approx 0$$

$$\tilde{k}_{t+1}^c \approx \tilde{k}_t^c \approx 0$$

where I assumed that the economy begins in steady state. Hence, in period $t + 1$, all state variables are zero and as a result, all variables dated $t + 1$ must be zero. Further note that equations (A1, A2) imply that for fixed ζ and arbitrarily small δ , $\frac{\widetilde{\gamma}_t^x}{\widetilde{p}_t^x} \approx \frac{\widetilde{\gamma}_t^c}{\widetilde{p}_t^c} \approx 0$. The Euler equations for capital (A3, A4) then yield $\text{d}r_t^x \approx 0$.

Now the above system simplifies to:

Labor supply decisions

$$\begin{aligned}\frac{1-\mu}{\eta}\tilde{n}_t + \frac{\mu}{\eta}\tilde{n}_t^x &\approx -\frac{1}{\sigma}\tilde{c}_t^h + \frac{\widetilde{p}_t^x}{p_t^c} + \frac{\widetilde{w}_t^x}{p_t^x} \\ \frac{1-\mu}{\eta}\tilde{n}_t + \frac{\mu}{\eta}\tilde{n}_t^c &\approx -\frac{1}{\sigma}\tilde{c}_t^h + \frac{\widetilde{w}_t^c}{p_t^c}\end{aligned}$$

Euler equation for nominal bond

$$-\frac{1}{\sigma}\tilde{c}_t^h \approx \beta \text{dr}_t^c$$

Labor aggregator

$$\tilde{n}_t \approx (1 - s_y^x)\tilde{n}_t^c + s_y^x\tilde{n}_t^x$$

Factor demands

$$\begin{aligned}\frac{\widetilde{w}_t^c}{p_t^c} &\approx -a\tilde{n}_t^c \\ \frac{\widetilde{w}_t^x}{p_t^x} &\approx -\alpha\tilde{n}_t^x\end{aligned}$$

Production functions

$$\begin{aligned}\tilde{x}_t &\approx (1 - \alpha)\tilde{n}_t^x \\ \tilde{c}_t &\approx (1 - \alpha)\tilde{n}_t^c\end{aligned}$$

Market clearing conditions

$$\begin{aligned}\tilde{x}_t &\approx s_x^x\tilde{x}_t^x + s_x^c\tilde{x}_t^c + s_x^g\tilde{x}_t^g \\ \tilde{c}_t &\approx (1 - s_c^g)\tilde{c}_t^h + s_c^g\tilde{c}_t^g\end{aligned}$$

Fisher equations

$$0 \approx \beta \text{dr}_t^c + \frac{\widetilde{p}_t^x}{p_t^c}$$

Real GDP

$$\tilde{y}_t \approx s_y^x\tilde{x}_t + (1 - s_y^x)\tilde{c}_t$$

The endogenous variables are $\tilde{n}_t, \tilde{n}_t^x, \tilde{n}_t^c, \tilde{c}_t^h, \frac{\widetilde{p}_t^x}{p_t^c}, \frac{\widetilde{w}_t^x}{p_t^x}, \frac{\widetilde{w}_t^c}{p_t^c}, \text{dr}_t^c, \tilde{x}_t, \tilde{c}_t, s_x^x\tilde{x}_t^x + s_x^c\tilde{x}_t^c, \tilde{y}_t$, a total of 12. Note that in the limiting approximation \tilde{x}_t^x and \tilde{x}_t^c are not separately determined. The variables $\frac{\widetilde{r}_{k,t}^c}{p_t^c}$ and $\frac{\widetilde{r}_{k,t}^x}{p_t^x}$ and the equations

$$\begin{aligned}\frac{\widetilde{r}_{k,t}^c}{p_t^c} &\approx (1 - \alpha)\tilde{n}_t^c \\ \frac{\widetilde{r}_{k,t}^x}{p_t^x} &\approx (1 - \alpha)\tilde{n}_t^x\end{aligned}$$

are redundant. The multipliers now follow from basic algebra. □

A.2.2 Proof of Proposition 2.2

Proposition. Consider the model Section 2.1 and assume that labor is mobile across sectors ($\mu = 0$). Then the long-run multipliers are

$$m_c^\infty = m_x^\infty = \frac{\eta}{\sigma(1-s_y^x)(1-s_c^g) + \eta[1-s_y^x(1-s_x^g)]},$$

where s_y^x denotes the steady state share of the investment sector in GDP.

Proof. Without loss of generality, I proof the proposition for the case without monopoly distortion. I consider permanent changes in x^g and c^g relative to their initial level and compare steady states. Begin with the system of equations as summarized in Appendix A.1, set $\mu = 0$, notice that $r^c, r^x, \frac{\gamma^x}{p^x}, \frac{\gamma^c}{p^c}, \frac{r_k^x}{p^x}, \frac{k^x}{n^x}$, and $\frac{w^x}{p^x}$ are independent of the level of government spending. Then the system of equation reduces to:

Labor supply conditions

$$\begin{aligned}\phi(n)^{\frac{1}{\eta}} &= (c^h)^{-\frac{1}{\sigma}} \frac{w^c}{p^c} \\ \phi(n)^{\frac{1}{\eta}} &= (c^h)^{-\frac{1}{\sigma}} \frac{1}{(\delta + r^x)} \frac{w^x}{p^x} \frac{r_k^c}{p^c}\end{aligned}$$

Labor aggregator

$$n = n^c + n^x$$

Capital accumulation equations

$$\begin{aligned}\delta \frac{k^x}{n^x} n^x &= x^x \\ \delta k^c &= x^c\end{aligned}$$

Factor demand functions

$$\begin{aligned}\frac{w^c}{p^c} &= (1-\alpha)(k^c)^\alpha (n^c)^{-\alpha} \\ \frac{r_k^c}{p^c} &= \alpha(k^c)^{\alpha-1} (n^c)^{1-\alpha}\end{aligned}$$

Production functions

$$\begin{aligned}x &= \left(\frac{k^x}{n^x}\right)^\alpha n^x \\ c &= (k^c)^\alpha (n^c)^{1-\alpha}\end{aligned}$$

Market clearing conditions

$$\begin{aligned}x &= x^x + x^c + x^g \\ c &= c^h + c^g\end{aligned}$$

Real GDP (holding prices p^x, p^c fixed)

$$y = p^x x + p^c c$$

The endogenous variables are $n^c, n^x, n, c^h, \frac{w^c}{p^c}, \frac{r_k^c}{p^c}, x^x, x^c, k^c, x, c, y$, a total of 12. Now approximate linearly around the old steady state and solve the system of 12 equations in 12 unknowns. □

Table A1: Symmetric and non-symmetric calibrations

Parameter	Symmetric	Non-symmetric	Notes
σ	0.25	0.25	Cashin and Unayama (2016), Hall (1988)
η	0.75	0.75	Chetty et al. (2011)
μ	1	1	0 for perfect labor mobility, 1 for immobile labor
β	0.995	0.995	
α	1/3	1/3	
δ	0.025	0.025	
ζ	2	2	Basu and Leo (2016)
ϱ_{gx}	0.86	0.86	Estimate in Section 3
ϱ_{gc}	0.86	0.96	Estimate in Section 3
s_x^g	0.175	0.17	U.S. NIPA 2005, Tables 1.1.5 and 3.9.5
s_c^g	0.175	0.185	U.S. NIPA 2005, Tables 1.1.5 and 3.9.5
θ_x	0.7	0.6	Klenow and Malin (2010)
θ_c	0.7	0.75	Galí, López-Salido, and Vallés (2007)
ϕ_π	1.5	n.a.	
ϕ_{π_c}	n.a.	1.5	Replace Taylor rule (14) with $di_t = \phi_{\pi_c} \pi_t^c$

A.3 A non-symmetric calibration

In this Appendix I discuss a calibration which takes differences between the consumption and investment goods sector into account. Relative to the symmetric benchmark calibration, I take into account that 1) government consumption shocks as identified in Section 3 are more persistent than government investment shocks, 2) the government purchases a slightly larger share from the consumption goods sector (18.5 percent vs. 17 percent), 3) durable goods have slightly less sticky prices (Klenow and Malin, 2010), and 4) the Federal Reserve targets personal consumption expenditure inflation rather than GDP deflator inflation. Table A1 summarizes both calibrations.

Figure A1 shows the impulse response functions for this non-symmetric calibration. The differences to the benchmark results as shown in Figure 1 are small. Figure A2 shows how the 4-quarter multipliers vary with the half-life of the shock. Again, there are only minor differences to the benchmark calibration as shown in Figure 3.

A.4 Supply elasticities

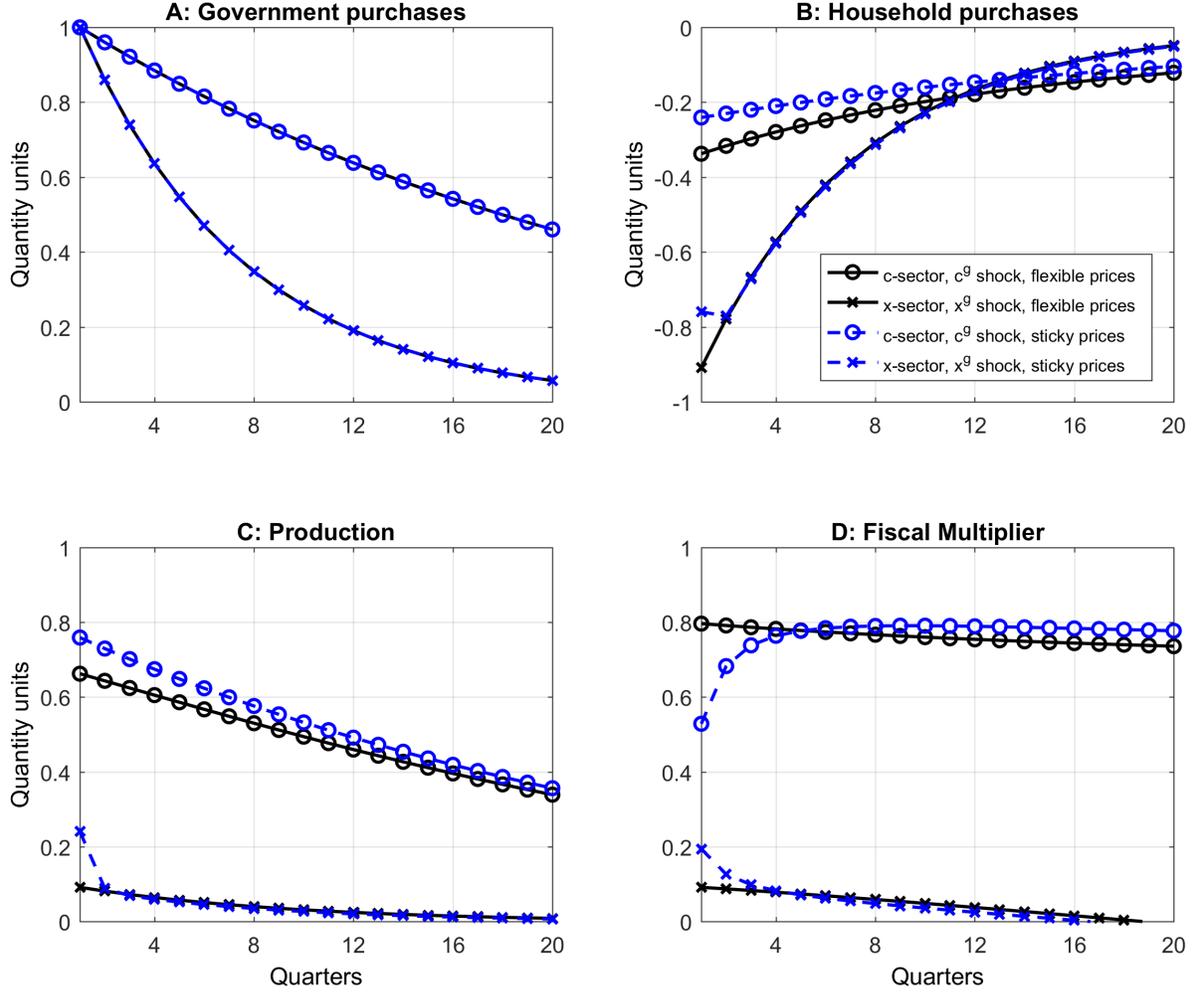
In Figure 2 I assumed that the consumption and investment goods sectors have equal supply elasticities. This follows from the production functions and the assumptions of labor supply.

Combining the Fisher equations for the consumption and investment goods sectors gives

$$(1 + r_t^x) E_t \left[\frac{p_{t+1}^x}{p_t^x} \right] = (1 + r_t^c) E_t \left[\frac{p_{t+1}^c}{p_t^c} \right].$$

Next, combine this relationship with the labor supply conditions (5) and (6), the labor demands (12) and

Figure A1: Impulse response functions for non-symmetric calibration



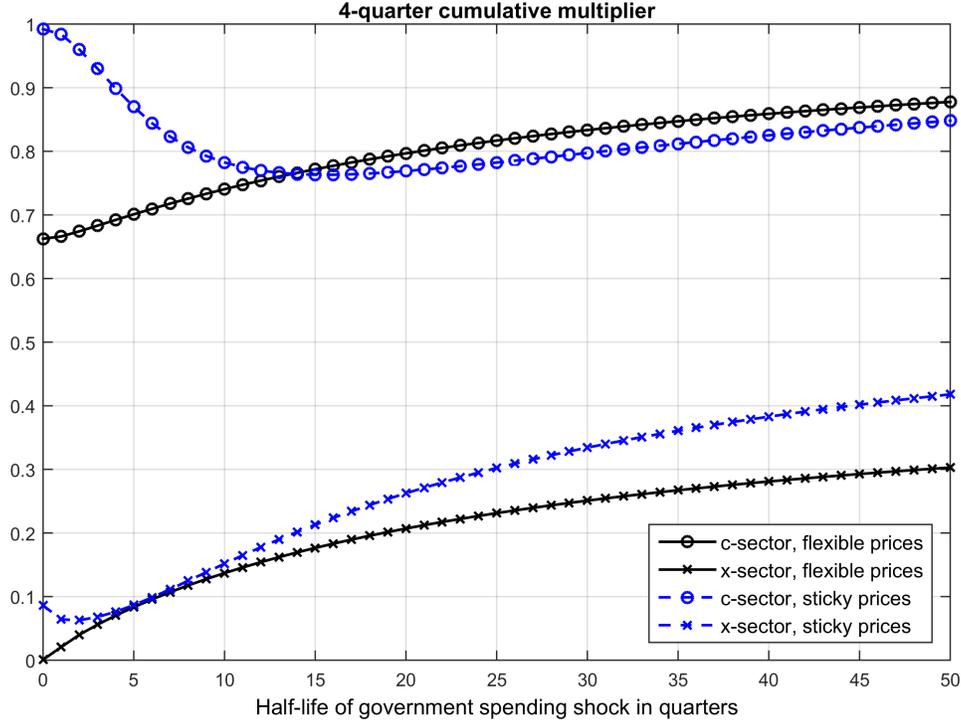
Notes: The figure plots the impulse response functions for a one unit increase in government spending based on the non-symmetric calibration (Table A1). Circles indicate responses to a government consumption shock and crosses indicate responses to a government investment shock.

the production functions (11) to obtain

$$(c_t)^{\frac{\alpha+\frac{\mu}{\eta}}{1-\alpha}} (1+r_t^x) = \frac{\frac{m c_t^c}{p_t^c} (k_t^c)^\alpha \frac{1+\frac{\mu}{\eta}}{1-\alpha}}{E_t \left[\frac{p_{t+1}^x}{p_{t+1}^c} \right] \frac{m c_t^x}{p_t^x} (k_t^x)^\alpha \frac{1+\frac{\mu}{\eta}}{1-\alpha}} (1+r_t^c) (x_t)^{\frac{\alpha+\frac{\mu}{\eta}}{1-\alpha}}. \quad (\text{A7})$$

This equation is simultaneously the supply curve for both sectors with (common and partial) supply elasticities $\frac{\partial \ln s_t}{\partial r_t^s} = \frac{1-\alpha}{\alpha+\frac{\mu}{\eta}}$, for $s \in \{c, x\}$. Note that in the approximation with flexible prices and purely transitory shocks, the fraction on the right hand side remains constant.

Figure A2: Short-run multipliers and shock persistence



Notes: The figure plots the 4-quarter cumulative multipliers using the non-symmetric calibration (Table A1), except for the shock persistence which is chosen to generate the half-lives as indicated on the horizontal axis.

A.5 Supplement for Section 2.3.2

Consider here, for simplicity, the case with immobile labor so that $\mu = 1$. Then, and using the approximation as discussed in Appendix A.2.1, equation A7 becomes up to a first order

$$\beta dr_t^c + \frac{\alpha + \frac{1}{\eta}}{1 - \alpha} \tilde{x}_t \approx \beta dr_t^x + \frac{\alpha + \frac{1}{\eta}}{1 - \alpha} \tilde{c}_t$$

Further, the demand functions in the two sectors are given by

$$\begin{aligned} \beta dr_t^c &\approx -\frac{1}{\sigma} \tilde{c}_t^h, \\ \beta dr_t^x &\approx 0. \end{aligned}$$

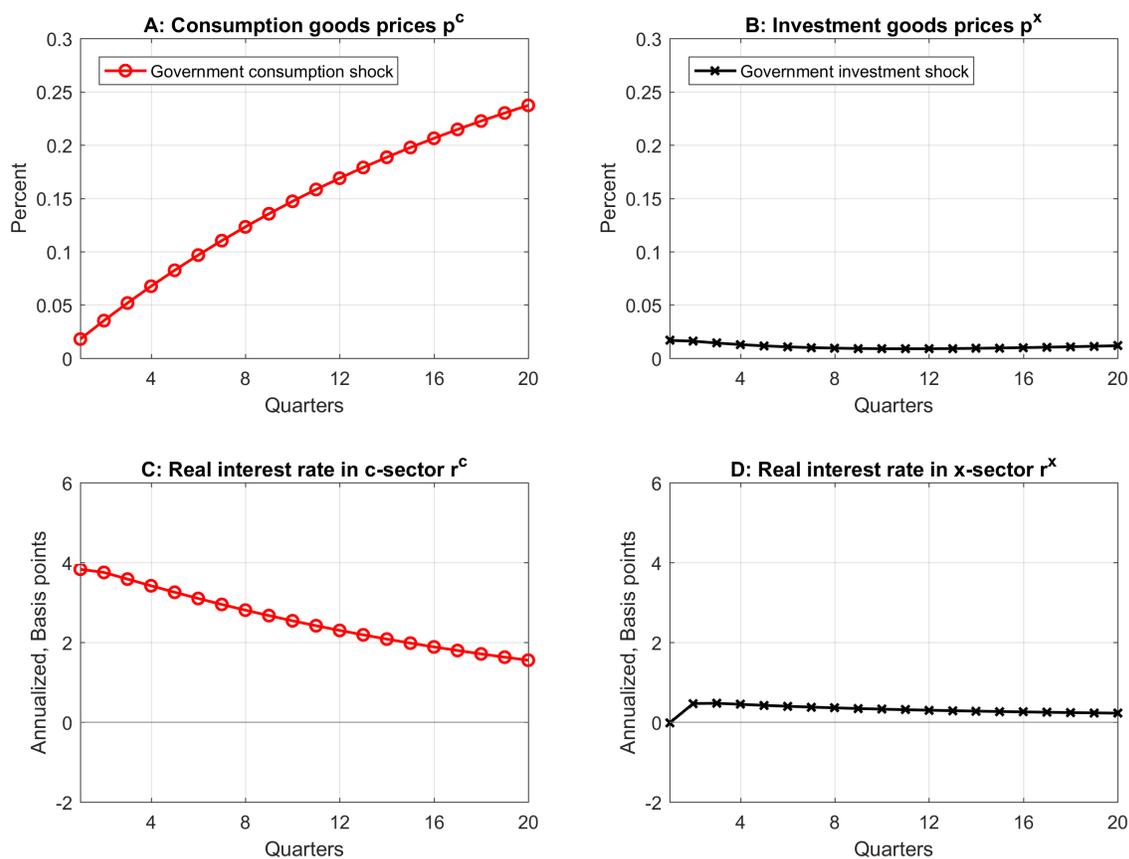
It is easily shown that if $\mu = 1$ then $\tilde{x}_t \approx 0$ in this approximation (see Appendix A.2.1). Now imposing market clearing and using the definition of real GDP yields the multipliers as given in equations (18 and 19).

A.6 Predictions for prices

In this appendix I discuss the model's predictions for the behavior of prices after government spending shocks.

Figure A3 presents the impulse response functions after a one percent increase in government spending

Figure A3: Prices and real interest rates in the model



Notes: The figure presents the impulse response functions of prices and own real interest rates to a one standard deviation government spending shock as measured in the data (Section 3). The figure is based on the non-symmetric calibration as summarized in Table A1.

over the steady state level. Panel A shows the impulse response function of the consumption goods price p^c after a shock to government consumption. The shock is followed by a persistent increase in inflation in that sector which translates into a gradual increase in the price level. When compared to the impulse response function of the investment price p^x to a government investment shock (Panel B), consumption goods prices rise by an order of magnitude more. The reason is, that investment demand is too price-elastic to support large changes in prices. Panel C and D show the impulse response functions of real interest rates. Both rise after a government spending shock in their own sector and again the increase is larger in the consumption goods sector. All impulse response functions are based on the non-symmetric calibration as summarized in Table A1.

B Data

B.1 Main data

The data come from editions 74 to 102 of the OECD Economic Outlook: Statistics and Projections Database. Editions 74 to 100 were downloaded on 01/27/2017. Editions 101 and 102 were downloaded on 01/10/2018. The variables are summarized in Table B1.

Different editions Forecasts of government spending and inflation expectations are constructed in real time and therefore use the edition of the database available up to that date. All other variables are constructed from the latest available edition. That is, if available, I use edition 102. If a particular variable is not available in edition 102, I use the same variable from edition 101, and so forth. Because the base years of all real variables and deflators vary by country within edition of the database and also across editions of the database, I convert all time series into variables which are independent of the base year. For instance, to use real GDP from an earlier edition, I do not use the level but convert it into a growth rate.

Manual fixes I apply a number of manual fixes when the data is unambiguously incorrect. For instance, the United Kingdom has a negative level of investment in the second quarter of 2005. I average the value of the first and third quarter to replace the negative value in quarter 2.

B.2 Notes on variable construction

Openness Openness is defined as imports plus exports divided by GDP.

Real Private Investment Real private investment is constructed from total and government investment (ITISKV, IGV, ITISK, and IG) using the Törnqvist approximation of the Fisher ideal index (see Whelan, 2000), whenever possible. Sometimes the nominal variables are not available. If this is the case, I construct the simple difference. I checked that the deflators are not trending relative to one another whenever I performed this operation, so that the simple subtraction does not introduce significant error.

Real total government purchases Real total government purchases are constructed from IGV, IG, CGV, and CG. As for real private investment I use the Törnqvist approximation of the Fisher ideal index to construct total government purchases whenever possible and used the simple addition of IGV and CGV as an alternative. I again checked that the deflators were not trending relative to one another.

Real interest rates I construct expected inflation as $(p_{t+4|t}^s - p_{t|t}^s) / p_{t|t}^s$, $s \in \{c, x\}$. For p^x I use PITISK and for p^c PCP. When the investment deflator PITISK is missing, I use

the deflator for total fixed investment PIT, which is highly correlated. I then construct the real interest rates for the consumption and investment goods sector based on the Fisher equation, using IRS as the measure for the nominal interest rate.

B.3 The zero lower bound

To define whether a country is at the zero lower bound, I use the variables IRSTCI (Immediate interest rates, Call Money, Interbank Rate, Per cent per annum) and IR3TIB (Short-term interest rates, Per cent per annum) from the OECD Main Economic Indicators: Finance database, downloaded 1/30/2018. An observation is defined to be at the zero lower bound if $IRSTCI \leq 0.75$. If IRSTCI is missing, I use IR3TIB instead.

Table B1: Data from the OECD Economic Outlook: Statistics and Projections database

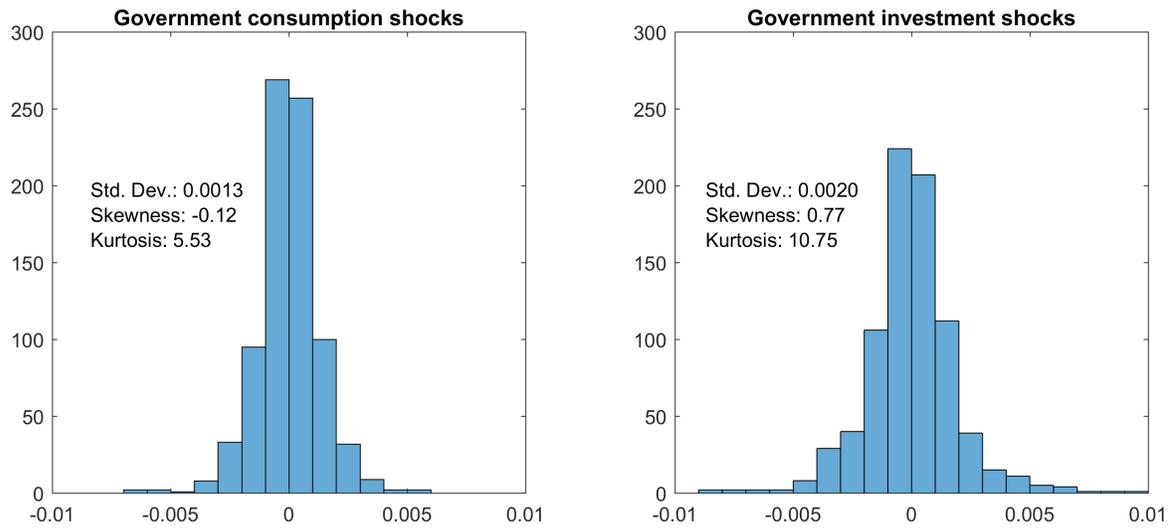
Variable	Variable code	OECD variable name	Download date
Real Gross Domestic Product	GDPV	Gross domestic product, volume, market prices	see text
Real Private Consumption	CPV	Private final consumption expenditure, volume	see text
Real Total Investment	ITISKV	Gross capital formation chained/constant prices	see text
Real Government Consumption	CGV	Government final consumption expenditure, volume	see text
Real Government Investment	IGV	Government gross fixed capital formation, volume	see text
Real Imports	MGSV	Imports of goods and services, volume, national accounts basis	see text
Real Exports	XGSV	Exports of goods and services, volume, national accounts basis	see text
GDP Deflator	PGDP	Gross domestic product, deflator, market prices	see text
Private Consumption Deflator	PCP	Private final consumption expenditure, deflator	see text
Total Investment Deflator	PITISK	Gross capital formation, deflator	see text
Government Investment Deflator	PIG	Government fixed capital formation, deflator	see text
Total Fixed Investment Deflator	PIT	Gross total fixed capital formation, deflator	see text
Nominal Gross Domestic Product	GDP	Gross domestic product, value, market prices	see text
Nominal Total Investment	ITISK	Gross capital formation, current prices	see text
Nominal Government Investment	IG	Government gross fixed capital formation, value	see text
Short-term interest rate	IRS	Short-term interest rate, percentage points	1/30/2018
Unemployment rate	UNR	Unemployment rate	see text
Total Government Revenues	YRGT	Total receipts, general government value	see text
Population	POP	Total Population	1/17/2018

Notes: All data are quarterly with two exceptions. First, total population is available only at an annual frequency. I interpolate the population linearly between quarters. Second, total government revenues are available at a quarterly level only for about half of the observations. When not available, I take annual data and interpolate linearly between quarters.

C Additional Results

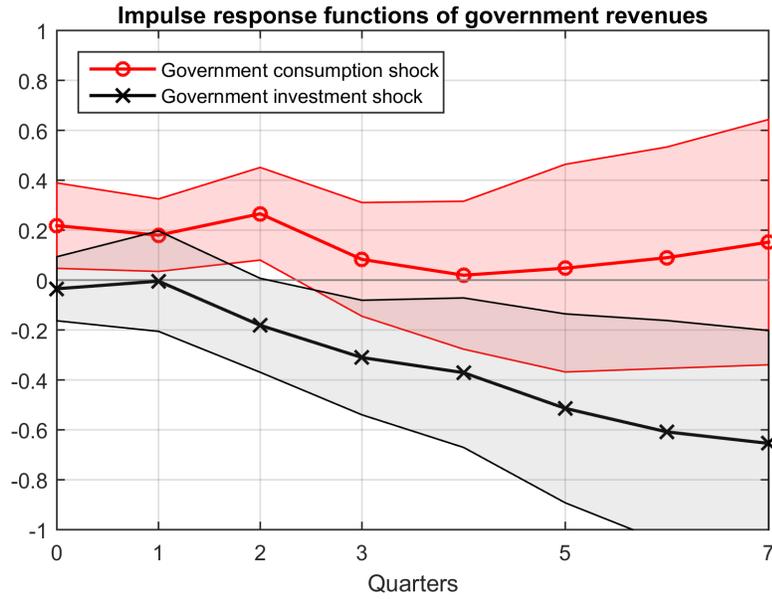
C.1 Additional tables and figures

Figure C1: Histograms of shocks



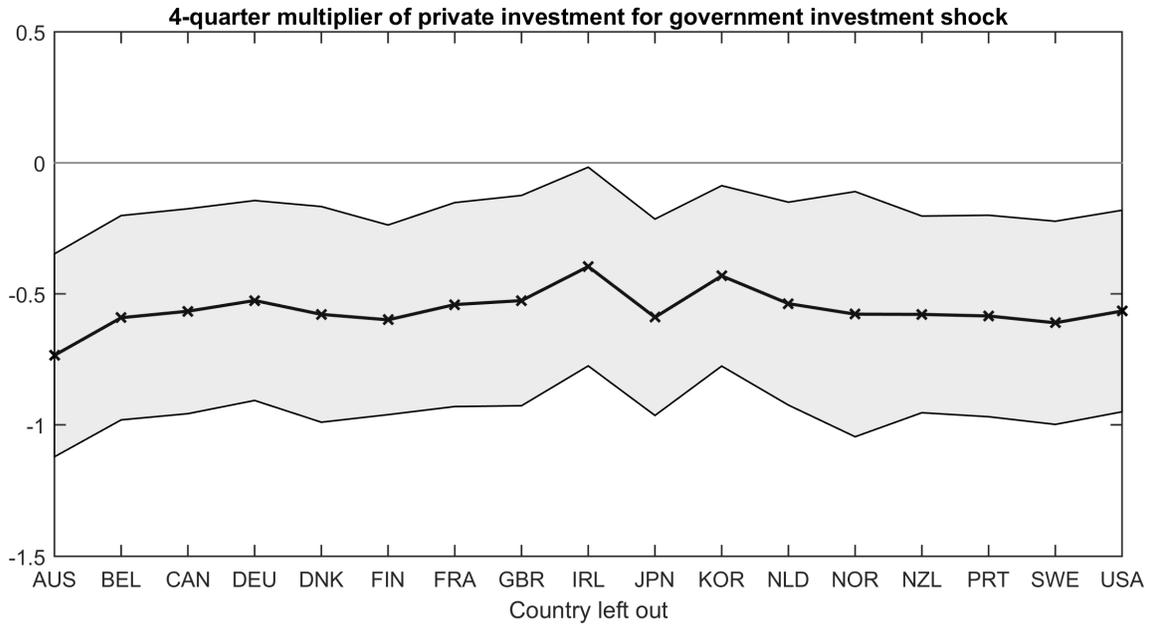
Notes: The histograms show the distribution of residuals from regression equation (22). For these illustrations I truncate the distributions below -0.01 and above 0.01.

Figure C2: Impulse response functions for government revenues



Notes: These estimates are based on specification (23) after replacing the left hand side with the h -quarter difference in nominal revenues divided by lagged nominal GDP. The shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

Figure C3: Leave-one-out estimation



Notes: These estimates are based on specification (23) using the baseline sample, but dropping one country at a time. The shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

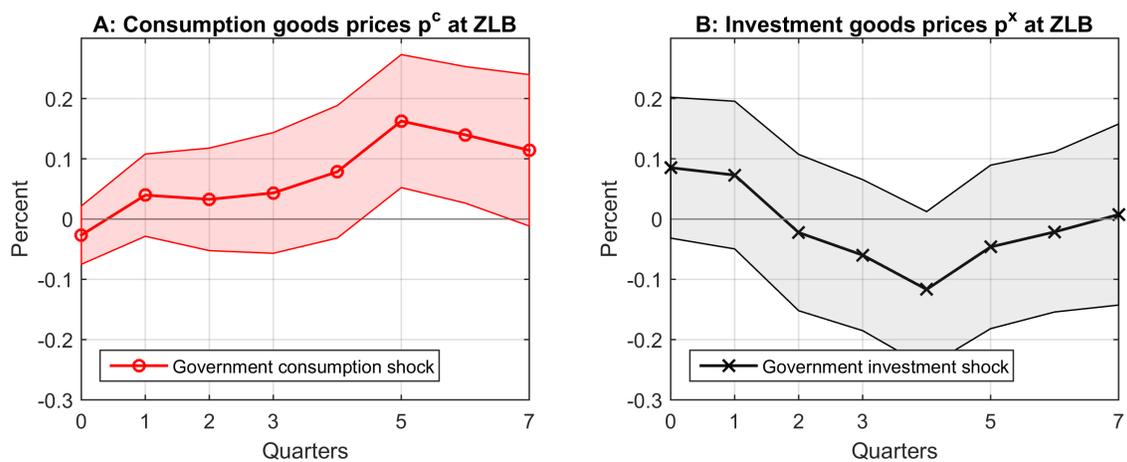
Table C1: Estimated multipliers for standard Blanchard-Perotti identification, extended sample

Horizon (quarters) LHS variable	Government consumption					Government investment					p-value of difference (percent)†				
	4	8	12	16	20	4	8	12	16	20	4	8	12	16	20
Gross domestic product	0.72*** (0.16)	0.89*** (0.20)	0.93*** (0.24)	1.01*** (0.26)	1.16*** (0.28)	0.20 (0.16)	0.10 (0.26)	0.05 (0.33)	0.06 (0.38)	0.00 (0.44)	4.7	4.0	5.8	6.6	5.0
Private consumption	0.15* (0.09)	0.27** (0.12)	0.32** (0.15)	0.37** (0.17)	0.43** (0.19)	0.08 (0.09)	0.01 (0.14)	-0.05 (0.18)	-0.07 (0.23)	-0.13 (0.28)	61.1	20.1	14.6	13.6	12.7
Private investment	0.09 (0.15)	0.28 (0.19)	0.30 (0.21)	0.36 (0.23)	0.46* (0.25)	-0.31* (0.17)	-0.46* (0.25)	-0.46 (0.30)	-0.44 (0.32)	-0.50 (0.36)	9.9	4.2	7.3	6.7	5.5
First stage F-statistic	469.2	231.5	162.8	123.08	102.68	146.94	92.00	73.95	51.86	44.46					
Observations	2116	2048	1980	1912	1844	2116	2048	1980	1912	1844					

Notes: The estimates are based on specification (24), but use the non-purified changes in purchases, $\frac{c_{i,t}^g - c_{i,t-1}^g}{y_{i,t-1}}$ and $\frac{x_{i,t}^g - x_{i,t-1}^g}{y_{i,t-1}}$, as instruments. The sample includes the same countries as those listed in Table 2, but spans the years 1980 to 2016. Driscoll-Kraay standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

Figure C4: Impulse response functions of prices at the zero lower bound



Notes: The impulse response functions are estimated based on equation (23) after replacing the left hand side with the percent change in prices $(p_{i,t+h}^s - p_{i,t-1}^s) / p_{i,t-1}^s$, $s \in \{c, x\}$. The controls include the baseline controls as well as four lags of the change in the relevant price. The sample is limited to observations at the zero lower bound and the impulse response functions are scaled to reflect a one standard deviation change in the respective measure of spending. Shaded areas are 90 percent confidence bands based on Driscoll-Kraay standard errors.

Table C2: Comparison of multiplier estimates, standard Blanchard-Perotti identification, extended sample

Panel A: Multiplier estimates						
Horizon (quarters)	Government consumption		Government investment		Total purchases	
	4	8	4	8	4	8
multiplier	0.72*** (0.16)	0.89*** (0.20)	0.20 (0.16)	0.10 (0.26)	0.37*** (0.10)	0.38*** (0.13)
First stage F-statistic	469.2	231.5	146.9	92.0	627.0	341.1
Observations	2116	2048	2116	2048	2116	2048

Panel B: Multipliers constructed from approximation (30)						
Horizon (quarters)	ω_c		ω_x		Total purchases	
	4	8	4	8	4	8
Weights	.415	0.446	.482	0.430		
GDP multiplier					0.396	0.441

Notes: The estimates in Panel A are based on specification (24), but use the non-purified changes in purchases, $(c_{i,t}^g - c_{i,t-1}^g)/y_{i,t-1}$ and $(x_{i,t}^g - x_{i,t-1}^g)/y_{i,t-1}$, as instruments. The sample includes the same countries as those listed in Table 2, but spans the years 1980 to 2016. Panel B reports the weights as stated in (31) and constructs the multiplier for total purchases from the government consumption and investment multipliers as reported in Panel A, using approximation (30). Driscoll-Kraay standard errors are reported in parentheses. *** denotes significance at the 1 percent level.

C.2 An alternative measure of slack

Table C3 reports state-dependent estimates of multipliers for an alternative measure of slack $_{i,t}$. I construct slack $_{i,t}$ as follows. First, I subtract from the unemployment rate the country-specific median. I then calculate the empirical counter-cumulative distribution function from this measure to map it into the unit interval. This mapping is almost identical to using the inverse logit specification in Auerbach and Gorodnichenko (2012, 2013), but avoids the choice of the parameter (γ in their case). The remainder of the estimation proceeds as described in Section 3.5.5. The key conclusion from these estimates is that, unlike the estimates reported in the text (Table 6), the government investment multiplier is no longer smaller in episodes of slack. Further, the point estimates of the government consumption multipliers are now *smaller* in times of slack. Clearly, the precise measure for slack strongly affects the results.

Table C3: Robustness: State-dependent multipliers

Panel A: High unemployment state ($\text{slack}_{i,t} = 1$)						
LHS variable	Government consumption		Government investment		p-value of difference [†]	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	0.19 (0.91)	-0.28 (0.80)	0.25 (0.41)	-0.03 (0.72)	0.953	0.802
Private consumption	-0.06 (0.43)	-0.49 (0.55)	0.25 (0.26)	0.03 (0.34)	0.596	0.488
Private investment	-0.90 (0.52)	-0.99 (0.65)	-0.88 (0.42)	-0.82 (0.64)	0.983	0.844
First stage F-statistic	30.4	20.8	33.1	22.5		
Observations	762	697	762	697		
Panel B: Low unemployment state ($\text{slack}_{i,t} = 0$)						
LHS variable	Government consumption		Government investment		p-value of difference [†]	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quart.	8 quart.
Gross domestic product	1.21 (0.61)	2.11 (0.83)	-0.21 (0.60)	-0.06 (0.92)	0.085	0.071
Private consumption	0.15 (0.31)	0.79 (0.50)	-0.17 (0.27)	-0.32 (0.48)	0.497	0.152
Private investment	0.44 (0.42)	1.40 (0.70)	-0.26 (0.47)	-0.95 (0.68)	0.283	0.035
First stage F-statistic	41.9	26.1	52.7	16.0		
Observations	762	697	762	697		
Panel C: p-value (H0: Equal multipliers over the business cycle)						
	Government consumption		Government investment			
	4 quarters	8 quarters	4 quarters	8 quarters		
Gross domestic product	0.471	0.118	0.619	0.983		
Private consumption	0.755	0.181	0.334	0.584		
Private investment	0.118	0.058	0.430	0.906		

Notes: Estimates are obtained as described in Section 3.5.5, but use an alternative measure of $\text{slack}_{i,t}$ (as described above). Driscoll-Kraay standard errors are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent level.

†: The null hypothesis is that the government consumption and investment multipliers are equal.

D Decomposition of total purchases multiplier

This appendix provides additional details on the relationship between the estimated multiplier for total government purchases and the multipliers for government consumption and investment as presented in Section 4.

Proposition. *Consider the three models*

$$\begin{aligned} y_{i,t} &= mg_{i,t} + q'_{i,t}\beta_g + \varepsilon_{i,t}^g, \\ y_{i,t} &= m_x x_{i,t}^g + q'_{i,t}\beta_x + \varepsilon_{i,t}^x, \\ y_{i,t} &= m_c c_{i,t}^g + q'_{i,t}\beta_c + \varepsilon_{i,t}^c, \end{aligned}$$

where $y_{i,t}$ is a common left hand side variable, $q_{i,t}$ a common vector of control variables, and

$$g_{i,t} = x_{i,t}^g + c_{i,t}^g.$$

There are instruments $z_{i,t}^g$ for $g_{i,t}$, $z_{i,t}^x$ for $x_{i,t}^g$, and $z_{i,t}^c$ for $c_{i,t}^g$, such that

$$z_{i,t}^g = z_{i,t}^x + z_{i,t}^c.$$

Then the exactly identified instrumental variable (IV) estimators satisfy

$$\hat{m}_g = \omega_x \hat{m}_x + \omega_c \hat{m}_c,$$

where

$$\omega_x = \frac{(M_Q z^x)' M_Q x^g}{(M_Q z^g)' M_Q g}, \quad \omega_c = \frac{(M_Q z^c)' M_Q c^g}{(M_Q z^g)' M_Q g},$$

and $M_Q = I - Q(Q'Q)^{-1}Q'$.

Proof. The proof is an application of the Frisch-Waugh-Lovell theorem. Begin with writing (25) in stacked (matrix) form

$$y = mg + Q\beta_g + \varepsilon^g. \tag{D1}$$

The moment conditions, split into g and Q , for the exactly identified IV estimator are

$$\begin{aligned} z' \left(y - \hat{m}g - Q\hat{\beta}_g \right) &= 0 \\ Q' \left(y - \hat{m}g - Q\hat{\beta}_g \right) &= 0 \end{aligned}$$

and these can be solved for

$$\hat{\beta}_g = (Q'Q)^{-1}Q'(y - \hat{m}g)$$

and hence

$$\hat{m} = \frac{(M_Q z)' M_Q y}{(M_Q z)' M_Q g}$$

where the matrix

$$M_Q = I - Q(Q'Q)^{-1}Q'$$

is idempotent and symmetric. (This matrix residualizes with respect to Q .)

Then simple algebra gives

$$\begin{aligned}\hat{m}_g &= \frac{(M_Q z^c)' M_Q y + (M_Q z^x)' M_Q y}{(M_Q z^g)' M_Q g} \\ &= \frac{(M_Q z^c)' M_Q c^g}{(M_Q z^g)' M_Q g} \frac{(M_Q z^c)' M_Q y}{(M_Q z^c)' M_Q c^g} + \frac{(M_Q z^x)' M_Q x^g}{(M_Q z^g)' M_Q g} \frac{(M_Q z^x)' M_Q y}{(M_Q z^x)' M_Q x^g}.\end{aligned}$$

Now note that

$$\hat{m}_x = \frac{(M_Q z^x)' M_Q y}{(M_Q z^x)' M_Q x^g} \quad \text{and} \quad \hat{m}_c = \frac{(M_Q z^c)' M_Q y}{(M_Q z^c)' M_Q c^g}$$

are the IV estimates of m_x and m_c in equations (26) and (27). Further,

$$\omega_x = \frac{(M_Q z^x)' M_Q x^g}{(M_Q z^g)' M_Q g} \quad \text{and} \quad \omega_c = \frac{(M_Q z^c)' M_Q c^g}{(M_Q z^g)' M_Q g}.$$

The claim now follows immediately. \square

I add three remarks. First, this proposition requires no assumption on the true underlying model. Under the stated conditions it holds exactly in the data. Second, the weights do not sum to one, due to cross terms

$$1 - \omega_x - \omega_c = \frac{(M_Q z^c)' M_Q x^g + (M_Q z^x)' M_Q c^g}{(M_Q z^g)' M_Q g}.$$

Third, replacing the instruments with the endogenous variables gives the result for the ordinary least squares (OLS) estimator.

In the text, I apply this formula after replacing y with Δy , the vector of $\sum_{j=0}^h \frac{y_{i,t+j} - y_{i,t-1}}{y_{i,t-1}}$, g with Δg , the vector of $\sum_{j=0}^h \frac{g_{i,t+j} - g_{i,t-1}}{y_{i,t-1}}$, x^g with Δx^g , the vector of $\sum_{j=0}^h \frac{x_{i,t+j}^g - x_{i,t-1}^g}{y_{i,t-1}}$, c^g with Δc^g , the vector of $\sum_{j=0}^h \frac{c_{i,t+j}^g - c_{i,t-1}^g}{y_{i,t-1}}$, z^x with the vector of residuals \hat{u}^x from equation (22), z^c with the vector of residuals \hat{u}^c (also equation 22), and z^g with the vector of residuals $\hat{u}^g = \hat{u}^c + \hat{u}^x$.

Finally note that this formula is not exact in the data for two reasons. First, chained indexes are not additive, so that equation (29) does not hold due to statistical discrepancy (see Whelan, 2000). Second, I prefer to estimate the government consumption multiplier while controlling for government investment shocks and the government investment multiplier while controlling for government consumption shocks. In other words, I add an additional control to equation (26) and (26). As I established in Section 3, these controls have little effect on the estimates, but break the identity in equation (30). As a result, we

have

$$\hat{m}_g \approx \omega_x \hat{m}_x + \omega_c \hat{m}_c.$$

Table D1 shows this breakdown numerically. In the table, the term *additive* indicates that I impose additivity by constructing total purchases as the sum of government consumption and investment. This is not in general a permissible operation with chained indexes, but the statistical discrepancy is small here. Further, *with controls* indicates that I control for the government investment shock when estimating the government consumption multiplier and that I control for the government consumption shock when estimating the government investment multiplier.

Panel A shows the baseline estimates as reported in Table 7. Panel B adds additivity by constructing total purchases as the sum of government consumption and investment. As a result, the multiplier for total purchases changes moderately. In Panel C, I drop the *other* spending shock as a control which mildly affects the government consumption and investment multiplier. When combined with the weights in Panel D, the estimates for the government consumption and investment multipliers in Panel C exactly aggregate into the multiplier for total purchases (equation 30).

Table D1: Breakdown of total purchases multiplier

Panel A: Baseline estimates: not additive, with controls						
Horizon (quarters)	Gov. consumption		Gov. investment		Total purchases	
	4	8	4	8	4	8
GDP multiplier	0.752	0.825	-0.065	-0.032	0.254	0.353

Panel B: additive, with controls						
Horizon (quarters)	Gov. consumption		Gov. investment		Total purchases	
	4	8	4	8	4	8
GDP multiplier	0.752	0.825	-0.065	-0.032	0.226	0.313

Panel C: Exact decomposition: additive, without controls						
Horizon (quarters)	Gov. consumption		Gov. investment		Total purchases	
	4	8	4	8	4	8
GDP multiplier	0.741	0.819	-0.019	0.027	0.226	0.313

Panel D: Weights						
Horizon (quarters)	ω_c		ω_x		$1 - \omega_c - \omega_x$	
	4	8	4	8	4	8
Weight	0.320	0.364	0.589	0.538	0.091	0.097

Notes: See text for details.