

# Government spending shocks, wealth effects and distortionary taxes

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## Abstract

The size and sign of the government spending multiplier crucially depends on how the spending is financed and how consumers respond to implied future tax increases. I investigate this issue in an estimated New Keynesian DSGE model with distortionary labor and capital taxes and, importantly, with preferences that allow the wealth effect on labor supply to vary. Specifically I assess whether the model can explain the empirical evidence for the United States and examine the transmission mechanism, for realistic policy rules. I show that the model can match the positive empirical response of key variables including output, consumption and the real wage. I find that the role of the wealth effect on labor supply is small and that while tax rates rise following a spending shock these increases are modest, with debt rising. Deficit financed spending increases are therefore expansionary, but this is due to sticky prices rather than the wealth effect channel.

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# 1 Introduction

The effectiveness of government spending in stimulating the economy became a central policy question during the 2008 financial crisis. Whilst proponents and critics argued about the mechanisms determining policy success, standard macroeconomic models can generate a wide range of theoretical predictions depending on the assumptions made about how the spending increase is financed and assumptions about how consumers respond to implied future tax increases.

The empirical literature<sup>1</sup> tends to find that GDP increases following a temporary shock to government spending. But from both an academic and policy perspective, an important question is why. And can a relatively standard modern macro model explain the findings observed in the time-series literature? The contribution of this paper is to investigate this issue by constructing and estimating a New Keynesian dynamic general equilibrium model but particularly focusing on the endogenous response of tax rates and debt to government spending and the strength of the so-called ‘wealth effect’ on labor supply.

Many neoclassical and New Keynesian models share the ability to replicate the expansionary nature of government spending increases. As is well-known, one of the most important channels is a negative wealth effect from higher lump sum taxes that generates a sizable increase in hours worked and output. In reality, however, governments levy distortionary, rather than lump sum, taxes.<sup>2</sup> Moreover, it is not obvious a priori that this ‘wealth effect’ channel — that government spending is expansionary because it makes consumers poorer — is quantitatively important in practice.

As shown by Baxter and King (1993), abandoning the lump sum tax assumption has significant implications in neoclassical models. If the extra government spending is fully financed by distortionary taxes every period, GDP will fall rather than increase. Burnside et al. (2004) therefore conclude that models which rely on lump sum taxes may produce misleading predic-

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<sup>1</sup>For example Blanchard and Perotti (2002) and Mountford and Uhlig (2009) using SVAR methods and Ramey (2011) using narrative methods.

<sup>2</sup>Romer and Romer (2010) and Cloyne (2010) document that many spending-driven tax changes affected marginal rates of tax. Furthermore, Drautzburg and Uhlig (2013) study how the financing of the recent American Recovery and Reinvestment Act will ultimately be financed by movements in distortionary taxes.

tions and assessing a model requires that it reflects a response of taxes that is “commensurate with what occurred in the data” (p.90). These negative effects can, however, be offset as more of the spending increase is deficit-financed. Due to Ricardian equivalence effects, deficit-finance in neoclassical models also leads to a wealth effect on labor supply.<sup>3</sup> However, if this channel is weak in practice, even debt financed spending increases could be contractionary: the negative effects of distortionary taxes are then likely to dominate. In New Keynesian models these contractionary forces remain strong, although can be somewhat offset by demand effects stemming from sticky prices.<sup>4</sup>

In assessing whether a model can account for the empirical evidence and the transmission mechanisms of fiscal policy, it is therefore important to first consider the degree of distortionary tax financing relative to debt financing. Second, to the extent that debt financing plays a role, the wealth effect channel will then be of crucial importance in determining whether the spending increase is expansionary.

I first estimate the empirical effects of a government spending shock in the United States using the common Structural VAR method of Blanchard and Perotti (2002).<sup>5</sup> The reason for this is to produce a baseline set of empirical impulse responses as close as possible to the existing literature. However, importantly — and unlike other papers — I estimate the response of distortionary tax rates and government debt. I show that both debt and taxes rise following a spending increase, although the increase is more debt financed (at least over the period considered).

I then examine whether, and how, a relatively standard medium-scale New Keynesian DSGE model can explain the evidence for plausible parameter values. As noted above, my focus is on ensuring the model matches the paths of tax rates and debt found in the data while allowing

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<sup>3</sup>Under certain assumptions, some of which are discussed later.

<sup>4</sup>Both Burnside et al. (2004) and Leeper et al. (2010) consider neoclassical flexible price models where tax rates move slowly following a government spending shock and the wealth effect remains an important driver of the positive output responses found.

<sup>5</sup>This methodology has been subject to concerns about whether the identified government spending shocks might be anticipated (for example, in Ramey (2011)). Later, I therefore employ the tests suggested by Ramey (2011) to guard against this concern.

the wealth effect on labor supply to vary in strength. To incorporate this feature, I follow Monacelli and Perotti (2009) who employ Jaimovich and Rebelo (2009) preferences. Following Schmitt-Grohe and Uribe (2012) I estimate the size of this effect (although these authors do not investigate the transmission mechanism of fiscal policy<sup>6</sup>). To my knowledge, this paper is the first to *empirically* assess the role of the wealth effect in the transmission of fiscal policy, and how this interacts with the financing of the shock. Other more common model features (such as habits, monetary policy and capital utilization) that are well-known to matter for the effects of fiscal policy are also included (see, for example, Leeper et al. (2011)).

I show that the estimated model can match the positive empirical response of key variables including output, consumption and the real wage, which is a challenge for many New Keynesian models, especially with a realistic set of tax instruments. The estimated model reveals three important aspects of why government spending increases are expansionary in the data. First, I find that the wealth effect on labor supply is small. Second, typical mechanisms such as sticky prices, variable capital utilisation, investment adjustment costs and habits all play a role. Third, distortionary tax rates rise following the expenditure shock but their small magnitude crucially reduces the distortions involved. These three results imply that the debt-financed nature of the spending increase is crucial for explaining the expansionary effect, although these expansionary effects do not depend on the wealth effect channel, but rather the presence of sticky prices.

While the consequences of distortionary taxes have been set out by Baxter and King (1993), McGrattan (1994) and others, only more recently have DSGE models begun to systematically quantify their importance. The inclusion of distortionary tax rules are popular in an expanding literature which investigates the effect of fiscal policy with DSGE models estimated using full information methods. For example, Forni et al. (2009) (for the Euro Area) and Leeper et al. (2010) and Zubairy (2013) (for the US) perform Bayesian estimation of models that include feedback rules for tax rates from output and debt (but not government spending). Leeper et al. (2010) consider the importance of different degrees of distortionary tax responses to debt, but this model does not include sticky prices. Coenen et al. (2012) examine fiscal multipliers and the

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<sup>6</sup>Schmitt-Grohe and Uribe (2012) focus more on the role of the wealth effect in the transmission of news shocks.

importance of different fiscal instruments across seven large-scale DSGE macro models.<sup>7</sup> Uhlig (2010) and Drautzburg and Uhlig (2013) focus on how future distortionary tax financing of the American Recovery and Reinvestment Act affects the overall impact of the programme. In general, however, these papers do not consider the importance of the wealth effect and therefore why debt financed spending increases may be more expansionary.

One important aspect of the estimated DSGE model literature is that it uses the estimated model *itself* to identify the effects of fiscal policy in the data. In contrast, the contribution of this paper is to examine how well a medium-scale DSGE model can account for, and help us understand, time-series evidence typically found elsewhere in the literature. I therefore estimate the model using limited information, minimum distance, methods which are particularly well suited for this task.<sup>8</sup>

This paper also relates to the more theoretical literature. One part of this literature has focused on why government spending shocks may have a positive effect on private consumption see, for example, Linnemann and Schabert (2003), Zubairy (2009)<sup>9</sup> and Ravn et al. (2012). As noted above, the most relevant paper for my purpose is Monacelli and Perotti (2009) who show that a low wealth effect on labor supply can potentially generate a positive response of consumption in New Keynesian models with lump sum taxes. Leeper et al. (2011), also in a relatively standard New Keynesian model, use predictive prior analysis to systematically examine which features most influence the size of the government spending multiplier, but only in theory. Other papers examine the issue of fiscal financing in theory, in more detail, for example Woodford (2011).

The remainder of the paper is structured as follows. Section 2 estimates the empirical effects of government spending shocks. Section 3 sets up the theoretical model. Section 4 illustrates key features of the model with respect to the tax policy rules, debt and the interaction with the wealth effect channel. Section 5 estimates the model using a minimum distance estimator. Section 6 concludes.

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<sup>7</sup>Such as those used in Central Banks and other policy institutions.

<sup>8</sup>And this approach is in the spirit of Burnside et al. (2004) and Reis (2008).

<sup>9</sup>Who also follows a minimum distance approach but specifically examines the importance ‘deep habits’ in a model with lump sum taxes.

## 2 The empirical effects of fiscal policy

### 2.1 Identification

This section establishes the empirical macroeconomic effects of a government spending shock that the model developed later should aim to explain. To remain as close as possible to the existing structural vector auto-regression literature on this topic, government spending shocks are identified using the method of Blanchard and Perotti (2002). Specifically I estimate the following VAR:

$$\mathbf{X}_t = B(L)\mathbf{X}_{t-1} + \mathbf{u}_t. \quad (1)$$

$\mathbf{X} = [g_t \ \tau^k \ \tau^n \ y \ c \ n \ w \ i \ b]'$  where  $g$  is government spending,  $\tau^k$  capital taxes,  $\tau^n$  labor taxes,  $y$  output,  $c$  consumption,  $n$  employment,  $w$  the real wage and  $i$  investment and government debt,  $b$ .  $B(L)$  is a lag polynomial of order four, as is common. The VAR is estimated including a linear trend. The vector  $X$  contains a range of variables we will be interested in later, particularly the fiscal policy instruments.

As is well known, the reduced form residuals  $\mathbf{u}_t$  are likely to be correlated. To identify the spending shock we follow the Blanchard and Perotti (2002) assumption that government spending is unaffected contemporaneously (within the same quarter) by changes in the other endogenous variables. This is justified by the institutional delays involved in policy decision-making. While this paper does not attempt to contribute to the literature on identifying fiscal shocks, this specification does allow me to study the effect of policy on labor and capital tax rates, as well as the response of government debt. These results should be of interest in their own right. Later, I will show that the theoretical model can jointly explain the relative magnitudes of the movements in tax rates and debt.<sup>10</sup>

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<sup>10</sup>A further reason for including a range of variables in the VAR is to help address concerns that typical SVARs contain too little information and, as a result, the identified ‘shocks’ may be anticipated (see, for example, Ramey (2011), Forni and Gambetti (2011), Mertens and Ravn (2010) and Leeper et al. (2012)). As a robustness check, I therefore conduct the test suggested by Ramey (2011). Having estimated government spending shocks using the SVAR, I examine whether these shocks are Granger caused by the Survey of Professional Forecasters expectations of the changes in government spending one and four quarters ahead. I follow the specification in Ramey (2011)

## 2.2 The data

The data are for the United States over the period 1955 Q1 to 2007 Q4. I exclude the Korean War because it is, to some extent, a unique event and can disproportionately drive the results (see Perotti (2007)). For a similar reason, I exclude the recent crisis period.

With the exception of the tax rates and debt, all data are taken directly from the relevant sources, such as the US Bureau of Economic Analysis. The capital and labor tax rates are constructed using the method outlined in Jones (2002). This approach is also adopted by Burnside et al. (2004), and various others, and is closely related to Mendoza et al. (1994).

The debt series would ideally be ‘Debt Held by the Public’, as used by Favero and Giavazzi (2007). However, this quarterly series does not go back far enough. I therefore construct a new historical debt series from old paper editions of the U.S. Treasury Bulletin. The resulting series is very close to ‘Debt Held by the Public’, see Appendix A for details.<sup>11</sup>

All variables, except the tax rates, are the log of real per capita variables. The tax rates are percentages. All real series are the nominal series deflated by its own implicit price deflator, with the exception of government spending and debt which are deflated by the GDP deflator. Appendix A sets out the specific details of each series.

## 2.3 Results

The figures below report the baseline results. The impulse response functions are simulations to a one percent structural shock to government spending. The point estimates are shown together with non-parametric bootstrapped confidence intervals using 10,000 replications.<sup>12</sup>

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and use the SPF data available from Valerie Ramey’s website. For the VAR above, reassuringly, I do not find that the government spending shocks are Granger caused by the forecasts, with p-values above 0.4. Of course this does not mean that anticipated shocks are unimportant. In fact, Schmitt-Grohe and Uribe (2012) argue that a third of government spending shocks are still unanticipated, suggesting results from different econometric approaches may be complementary.

<sup>11</sup>Favero–Giavazzi simulate the debt series back to 1947 using annual data.

<sup>12</sup>To make it harder for the model to match the point estimates, the IRFs are shown with one-standard deviation error bands. These have been common in this branch of the fiscal policy literature following Blanchard and Perotti (2002).

Figure 1 shows the response of the other fiscal policy variables to the shock. The response of the labor and capital tax rates, although positive (as one might expect) are relatively modest. Given the modest increase in taxes, it is also useful to consider the response of debt. To the extent that lump sum taxes are rarely used to satisfy the government budget constraint, modest tax rate increases would imply a larger increase in debt. This is indeed what is observed in the fourth panel of Figure 1.

Figure 2 shows the responses of the other variables in the SVAR. The top two panels show the familiar SVAR result that output and consumption rise following a government spending shock.<sup>13</sup> The output response on impact is 0.2, which implies an output multiplier on impact of around one. This paper focuses directly on the impulse response functions from the VAR and the model, although these can always be converted into “multipliers”. There is, of course, a wider literature on multipliers, both on impact and in present value terms see, for example, Leeper et al. (2011).

Consumption exhibits the hump-shaped response often seen in SVAR results. The investment response is generally negative, a feature often found elsewhere, although the response is quite noisy and relatively imprecise.<sup>14</sup> Interestingly the labor market responses are weaker, although the point estimates are generally still positive. These findings are comparable with the wider literature, such as Perotti (2007) and Monacelli and Perotti (2009). For the purpose of the next section, I take these findings as empirical regularities for the model to match.

### 3 The model

As discussed in the introduction, this paper focuses on whether a New Keynesian model can explain the empirical evidence for a realistic set of parameter values. However, to directly address the issues raised earlier, I particularly focus on the role of distortionary capital and labor tax rates and allow for endogenous tax rate responses to government spending shocks. I also employ Jaimovich and Rebelo (2009) preferences which allow the strength of the wealth

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<sup>13</sup>In contrast, using a narrative approach based on military expenditures, Ramey (2011) shows that consumption may actually fall following a government spending shock.

<sup>14</sup>Cloyne (2013) also finds this to be the case for investment following tax changes.



effect on labor supply to vary. Finally, the model includes a range of more standard features such as sticky prices, variable capital utilisation and habits.

### 3.1 Households

Households derive utility from consumption ( $C$ ) and leisure ( $1 - N$ ). The household maximises lifetime utility

$$\max_{C_t, N_t, I_t, z_t, K_{t+1}, B_{t+1}} \mathbb{E}_t \sum_{t=s}^{\infty} \beta^{t-s} u(C_{t+s}, 1 - N_{t+s}), \quad (2)$$

subject to a budget constraint (in real terms)

$$C_t + I_t + \frac{B_{t+1}}{R_t} = B_t + w_t N_t (1 - \tau_t^N) + r_t^K (z_t) (1 - \tau_t^K) K_t - T_t. \quad (3)$$

The capital stock evolves according to

$$K_{t+1} = (1 - \delta(z_t)) K_t + I_t \left( 1 - \phi \left( \frac{I_t}{I_{t-1}} - 1 \right) \right), \quad (4)$$

which incorporates adjustment costs employed by Christiano et al. (2005), among others. The utility function,  $u : \mathbf{R}^2 \rightarrow \mathbf{R}$ , is assumed to be concave and twice continuously differentiable. The function  $\phi$  satisfies  $\phi = \phi' = 0$  and  $\phi'' > 0$ .

$K_{t+1}$  denotes capital held by households at the end of period  $t$  and  $B_{t+1}$  are real holdings of government bonds, also at the end of period  $t$ .  $C_t$  is consumption,  $I_t$  is investment,  $R_t$  is the aggregate real interest rate (gross),  $w_t$  is the aggregate real wage and  $r_t^K$  is the real return on capital.  $\tau_t^K$  and  $\tau_t^N$  are the tax rates on capital and labor income respectively.  $T_t$  are lump sum taxes.  $\delta$  is the rate of depreciation.

The parametric specification for the utility function  $u(\cdot)$  follows Jaimovich and Rebelo (2009), Schmitt-Grohe and Uribe (2012) and Monacelli and Perotti (2009).

$$U(C_t, N_t) = \frac{(C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{1-\sigma}}{1-\sigma} \quad (5)$$

where

$$X_t = (C_t - h\tilde{C}_{t-1})^\gamma X_{t-1}^{1-\gamma}. \quad (6)$$

For  $\gamma = 1$  and  $h = 0$  these preferences become those considered by King et al. (1988). For  $\gamma = 0$  and  $h = 0$  they become the preferences considered by Greenwood et al. (1988) (henceforth GHH).<sup>15</sup> The latter preferences exhibit no wealth effect on labor supply. In other words, labor supply is solely affected by the real wage (net of taxes) and not by the level of consumption.

I have modified the Jaimovich–Rebelo preferences to include habits.  $\tilde{C}_{t-1}$  is aggregate consumption in the previous period and the consumer takes this as given. Below I show that internal habits, where consumers explicitly consider  $C_{t-1}$  in their optimisation decisions, would reintroduce the wealth effect on labor supply when  $\gamma = 0$ .

The model also features variable capital utilisation. High utilisation by firms implies greater depreciation of a given stock of capital. For this reason both the return on capital and the depreciation are functions of utilisation, captured by the variable  $z_t$ .

### 3.1.1 First order conditions

The first order conditions for the household's problem, with respect to  $C_t$ ,  $X_t$ ,  $B_{t+1}$ ,  $N_t$ ,  $I_t$ ,  $K_{t+1}$  and  $z_t$  are:

$$\lambda_t = (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma} + \mu_t \gamma (C_t - h\tilde{C}_{t-1})^{\gamma-1} X_t^{1-\gamma} \quad (7)$$

$$(C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma} \psi N_t^\xi + \mu_t = \beta \mathbb{E}_t(\mu_{t+1}(1 - \gamma)(C_t - h\tilde{C}_{t-1})^\gamma X_t^{-\gamma}) \quad (8)$$

$$\mathbb{E}_t \left( \frac{\lambda_{t+1}}{\lambda_t} \right) = \frac{1}{R_t \beta} \quad (9)$$

$$\psi N_t^{\xi-1} \xi X_t (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma} = \lambda_t w_t (1 - \tau_t^n) \quad (10)$$

$$1 - q_t \left( \left( 1 - \phi \left( \frac{I_t}{I_{t-1}} \right) \right) - \phi' \left( \frac{I_t}{I_{t-1}} \right) \left( \frac{I_t}{I_{t-1}} \right) \right) = \mathbb{E}_t \left( q_{t+1} \frac{\lambda_{t+1}}{\lambda_t} \beta \left[ \frac{I_{t+1}^2}{I_t^2} \phi' \left( \frac{I_{t+1}}{I_t} \right) \right] \right) \quad (11)$$

$$q_t = \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} (r_{t+1}^K (1 - \tau_{t+1}^K) + q_{t+1} (1 - \delta(z_t))) \quad (12)$$

$$r_t^K(z_t) = q_t \delta'(z_t) \quad (13)$$

where  $r'^K$  is the derivative of the return on capital with respect to utilisation.  $\mu_t$  is the Lagrange multiplier on the evolution of  $X_t$  (equation (6)) and  $q_t$  is the multiplier on the capital accumulation equation and reflects Tobin's marginal q.

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<sup>15</sup>One reason against simply using GHH preferences is that they fail to satisfy the conditions for balanced growth, see King and Rebelo (1999) and Jaimovich and Rebelo (2009).

### 3.1.2 The variable wealth effect

Consider the extreme case where  $\gamma = 0$ . The preferences are then of the GHH-form and the marginal rate of substitution between consumption and leisure is independent of consumption. To see this, combine the first order condition with respect to consumption with the first order condition with respect to labor supply:

$$\psi N_t^{\xi-1} \xi X_t (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma} = (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma} w_t (1 - \tau_t^n) \quad (14)$$

noting

$$\lambda_t = (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi X_t)^{-\sigma}. \quad (15)$$

This implies that

$$\psi \xi N_t^{\xi-1} = w_t (1 - \tau_t^n). \quad (16)$$

At an unchanged real wage and tax rate, hours do not change. In a simple graphical representation without capital, this implies that the labor supply curve does not shift outwards as consumption falls (the key neoclassical channel). Under Jaimovich–Rebelo preferences, increasing  $\gamma$  from zero raises the strength of the wealth effect on labor supply and this feature is preserved under the habits specification introduced above. Note, however, that this would not be true with internal habits. For  $\gamma = 0$ ,  $\lambda_t$  would then become:

$$\lambda_t = (C_t - h\tilde{C}_{t-1} - \psi N_t^\xi)^{-\sigma} - \mathbb{E}_t \lambda_{t+1} h \beta (C_{t+1} - h\tilde{C}_t - \psi N_{t+1}^\xi)^{-\sigma}. \quad (17)$$

The first order condition for labor supply would be unchanged. This implies that  $\lambda_t$  would no longer cancel in equation (14) and labor supply once again depends on consumption.

## 3.2 Firms

There are a continuum of monopolistically competitive firms producing final output indexed on the unit interval. The consumer's problem can still be formulated as above but note that each individual actually purchases a bundle of differentiated goods  $\int_0^1 P_t(i) C_t(i)$  where  $i$  refers to a particular firm. For each variety of goods the consumption demand function is:

$$C_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} C_t, \quad (18)$$

where

$$P_t = \left( \int_0^1 P_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \quad (19)$$

and  $\epsilon$  is the elasticity of substitution between varieties of goods.

The minimum expenditure required to purchase a bundle of goods resulting in  $C_t$  units of the composite good is given by  $P_t C_t$  and so the consumer's budget constraint can be written as before.<sup>16</sup>

The demand for the  $i^{th}$  product (the output of firm  $i$ ) is given by

$$Y_t(i) = \left( \frac{p_t(i)}{P_t} \right)^{-\epsilon} Y_t^d, \quad (20)$$

where  $Y_t^d$  is aggregate demand. The resource constraint is

$$Y_t = C_t + I_t + G_t. \quad (21)$$

Cost minimization with respect to  $N_t(i)$ ,  $K_t(i)$  and  $z_t(i)$  subject to firm  $i$ 's production function  $Y_t(i) = [z_t(i)K_t(i)]^\alpha N_t(i)^{(1-\alpha)}$  implies

$$w_t = mc_t(i)(1 - \alpha) \frac{Y_t(i)}{N_t(i)} \quad (22)$$

$$r_t^K = mc_t(i)\alpha \frac{Y_t(i)}{K_t(i)}, \quad (23)$$

and

$$mc_t(i)\alpha \frac{Y_t(i)}{z_t(i)} = \frac{q_t \delta'(z_t(i)) k_t(i)}{(1 - \tau_t^K)} \quad (24)$$

where  $mc_t(i)$  is real marginal cost and equation (24) makes use of equation (13).

Sticky prices are introduced following Calvo (1983). Firms can adjust their price with probability  $\eta$ . When firms are able to reset their price they choose  $P_t^*(i)$  to maximize expected profits

$$\max \mathbb{E}_t \sum_{j=0}^{\infty} Q_{t,t+j} \eta^j \left[ (1 - \tau^P) P_{t+j}^*(i) Y_{t+j}(i) - MC_{t+j}(i) Y_{t+j}(i) + T_{t+j}^P \right] \quad (25)$$

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<sup>16</sup>The consumer's problem technically also includes non-zero profits  $\Pi_t$  which I assume are equally distributed lump sum to all consumers. This does not affect the first order conditions.

subject to

$$Y_{t+j}(i) = \left( \frac{P_{t+j}(i)}{P_{t+j}} \right)^{-\epsilon} Y_{t+j}^d,$$

where  $MC_t$  is nominal marginal cost.  $\tau^P$  and  $T^P$  are a tax and lump sum subsidy, which removes the steady state markup distortion.

The first order condition for firm  $i$ 's price setting problem is the familiar New Keynesian optimal reset price:

$$P_t^*(i) = \frac{\mathbb{E}_t \sum_{j=0}^{\infty} \eta^j Q_{t,t+j} MC_{t+1} Y_{t+j}(i)}{\mathbb{E}_t \sum_{j=0}^{\infty} \eta^j Q_{t,t+j} Y_{t+j}(i)}. \quad (26)$$

Finally, the price index is an aggregate of firms who reset their price today and those who must retain last period's prices:

$$P_t = \left[ \eta P_{t-1}^{1-\epsilon} + (1-\eta) P_t^{*(1-\epsilon)} \right]^{\frac{1}{1-\epsilon}}. \quad (27)$$

### 3.3 Policy

The government can finance spending,  $G$ , through a mixture of bond supply  $B$ , labor and capital income taxes  $\tau^N, \tau^K$  or lump sum taxes  $T$ , such that the government budget constraint is satisfied

$$\frac{B_{t+1}}{R_t} = B_t + G_t - \tau_t^N N_t w_t - \tau_t^K K_t r_t^K - T_t. \quad (28)$$

Tax rules are necessary to specify how the government splits its financing between the various policy instruments. I assume tax rates respond to a proportion of the spending increase and these responses are persistent.  $\hat{\tau}$  are tax rates as the percentage point deviation from steady state, and all other lower case letters as percentage deviation from steady state. Following

McGrattan (1994) I employ an AR(2) structure for the linearized tax rules as follows:<sup>17</sup>

$$\hat{\tau}_t^N = \theta^{\tau^{N,1}} \hat{\tau}_{t-1}^N + \theta^{\tau^{N,2}} \hat{\tau}_{t-2}^N + \theta^{ng} g_t \quad (29)$$

$$\hat{\tau}_t^K = \theta^{\tau^{K,1}} \hat{\tau}_{t-1}^K + \theta^{\tau^{K,2}} \hat{\tau}_{t-2}^K + \theta^{kg} g_t \quad (30)$$

I follow Reis (2008) in making government spending ARMA(1,1)

$$g_t = \phi_1 g_{t-1} + \phi_2 a_t, \quad (31)$$

where  $a_t$  is an AR(1) process with a white noise shock and the persistence is governed by parameter  $\rho$ . Lump sum taxes are not used, as discussed in the introduction.

Monetary policy follows a familiar Taylor rule. In percentage deviations from steady state the nominal interest rate  $r_t$  is set as follows:<sup>18</sup>

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)(\phi_\pi \pi_t + \phi_y y_t). \quad (32)$$

### 3.4 The linearized model

The model is linearized around its steady state and solved. Details of the linearized system and the steady state are given in Appendices B and C. Of particular interest are the linearized equations governing price evolution, utilisation and investment (recall, lower case letters represent percentage deviations from steady state). The first is the New Keynesian Phillips Curve. Note that the degree of price stickiness,  $\eta$ , appears in this expression and will be estimated.

$$\pi_t = \frac{(1 - \beta\eta)(1 - \eta)}{\eta} mc_t + \beta \mathbb{E}_t \pi_{t+1}. \quad (33)$$

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<sup>17</sup>Mertens and Ravn (2011) also employ an AR(2) specification. In principle, I could consider a more general rule with feedback from output and debt. However, since I am matching the empirical path of taxes and debt from the SVAR, in practice this makes little difference as I show in Appendix D. In the baseline model I back out the path for debt after solving the model. In the appendix, the model also explicitly includes debt and feedback in the tax rules.

<sup>18</sup>To limit the number of parameters estimated I will, in the baseline specification, consider the case with  $\phi_\pi = 1.5$  only. However, in Appendix D I show this makes little difference to the results of the model, when all parameters of this rule are estimated.

The degree of capital utilisation,  $z_t$ , is described by

$$(1 + \kappa)z_t = y_t - k_t - q_t + mc_t - \tau_t^K \frac{1}{1 - \tau^K}, \quad (34)$$

where  $\kappa = \frac{\delta''}{\delta'}$  is the elasticity of depreciation to utilisation, and will also be estimated. Investment evolves according to

$$\frac{q_t}{\phi''} = (1 + \beta)i_t - i_{t-1} - \beta\mathbb{E}_t i_{t+1} \quad (35)$$

and  $\frac{1}{\phi''} = \mu$  will be estimated.

## 4 Key features of the model

### 4.1 The wealth effect channel

Figures (3) to (7) illustrate the effect of turning on each mechanism in the model one at a time while still assuming that lump sum taxes or debt funds the spending shock.<sup>19</sup>

In Figure (3), the model has flexible prices ( $\eta = 0$ ), no variable capital utilisation ( $\kappa = \infty$ ) and no habit formation ( $h = 0$ ).  $\gamma = 1$ , so there is a standard wealth effect on labor supply. This case can therefore be regarded as a simple baseline neoclassical model. Figure (3) shows the familiar neoclassical result. The higher lump sum taxes that accompany the spending shock lower lifetime wealth, lower consumption, lower savings and hence investment, but boost labor supply. The real wage therefore falls. Figure (4), however, illustrates the effect of turning off the wealth effect on labor supply, i.e. setting  $\gamma = 0$ . Labor supply now does not respond to the lower lifetime wealth. Consumption and investment are even lower than before, reflecting the decrease in lifetime wealth and the lack of increased earnings from supplying more labor. All these forces cause output to fall over time. Importantly, the neoclassical model can no longer match the empirical output response. In fact the neoclassical model without a wealth effect on labor supply fails to qualitatively match *any* of the output, consumption, real wage or hours responses estimated in Section 2. Unlike in Burnside et al. (2004) or Baxter and King (1993), even debt financed increases will be contractionary.

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<sup>19</sup>Without distortionary taxes, lump sum tax and debt financing is equivalent due to Ricardian equivalence.

Figure (5) shows the result of adding sticky prices to the previous model ( $\gamma = 0$ ). As Figure (5) illustrates, government spending now has a positive effect on demand which boosts output, labor demand, hours worked, the real wage, and consumption. The figure illustrates the Monacelli and Perotti (2009) result that consumption can rise following the shock. Without a wealth effect on labor supply the real wage does not fall on impact. The sticky price demand effect then induces an outward shift of the labor demand curve, raising real wages, hours and consumption.

Adding variable capital utilisation to the model serves to increase the persistence of these effects and moderates the volatility in investment, as can be seen from Figure (6). Finally, the inclusion of habits adds persistence to the consumption profile, with additional implications for overall demand. This can be seen from Figure (7).

## 4.2 Fiscal financing

I now consider how the choice of tax and debt instruments affects the model's predictions. Figure (8) illustrates the effect of assuming that the two distortionary tax rates increase following the spending shock. For this exercise I arbitrarily choose  $\theta^{gn} = \theta^{gk} = 0.6$ . The figure illustrates the strong negative effect on output and consumption of using distortionary taxes, relative to Figure (7). In short, the results in the previous section depend not only on the strength of the wealth effect on labor supply, but also — quite dramatically — on the instruments used to finance the shock. I now consider the two types of taxes individually.

Consider the effects of a rise in the labor income tax rate. There are two substitution effects. First, the intra-temporal decision is distorted and labor supply falls. In other words, it is more costly to supply labor today as the worker pays higher taxes per hour. Second, the inter-temporal decision is distorted if the tax rate is changing over time (as it may be when the tax rules are estimated). For a rising (falling) tax profile the worker may still prefer (dislike) to work today as it will be relatively less (more) costly than tomorrow. These substitution effects work to offset any wealth effect on labor supply and in the simulations below, labor supply falls considerably following a rise in government spending.

To illustrate the effect, I calibrate the coefficient on  $g_t$  in the labor tax rule to be 0.95, leaving



the equivalent parameter zero in the capital tax rule. Figure (9) shows the strong negative effect of this change in the tax policy rule. The positive effects on output, consumption and hours in the previous section are now reversed in the presence of labor income tax-finance. Note that saving becomes more attractive which, over time, raises investment.

I now turn to examine the effect of using capital taxes. Figure (10) shows the effect of calibrating the coefficient on  $g_t$  in the capital tax rate rule to 0.95, leaving the equivalent coefficient zero in the labor tax rule. Interestingly, the use of capital taxes raises consumption and output on impact but lowers the persistence. This effect is a combination of substitution effects and sticky prices (and habits). Taxing capital makes consumption relatively more attractive than saving. As a result, *ceteris paribus*, the balance between consumption and saving tilts towards consumption. This increase in demand, given sticky prices, boosts output in the short run. If prices were flexible, the increase in capital taxes would tend to lower consumption and output as the capital stock declines.

A number of important implications arise from the model. First, as expected, deficit financing minimizes the contemporaneous distortions associated with labor and capital taxes. This means that deficit financed spending increases tend to be expansionary, and distortionary tax funded increases tend to be contractionary (as in Baxter and King (1993)), and even in my model with sticky prices. Second, the type of tax matters: labor income taxes produce a strong negative effect on all the key variables, while capital income taxes may raise the impact stimulus by boosting consumption, but will lower the persistence of the effect on output as the capital stock declines faster. Third, deficit financed spending increases may be expansionary due to a wealth effect on labor supply. But if this channel is weak in practice, sticky prices may become important for explaining the expansionary effects of a spending shock on output found in Section 2.

In short, the choice of tax instruments and the degree of debt-financing matters greatly, as does the strength of the wealth effect on labor supply. In fact, the model's results are highly dependent on these parameters. However, there is no a priori reason to calibrate either the tax policy rules in a particular way, or to assume a particular strength for the wealth effect channel. To properly evaluate the ability of the model to explain the effects of a government

spending shock, arbitrarily calibrating these key parameters will not be enlightening. Estimation is therefore the most appropriate strategy to follow.

## 5 Estimation

As discussed above, without a good a priori reason to calibrate key parts of the model in a particular way, I estimate the model using a minimum distance approach as discussed by, for example, Christiano et al. (2005). Key parameters of the model are chosen to minimize the distance between the model’s impulse responses and the empirical impulse responses.

As discussed in the introduction, the contribution of this paper is to examine the transmission mechanisms of fiscal policy using a New Keynesian DSGE model and whether a relatively standard model can explain time series evidence for reasonable parameter values. In particular, I focus on the role of financing and how this interacts with the wealth effect channel. Minimum distance estimation methods are therefore very appealing for this exercise. I do not use the model itself to identify the response of the macroeconomy to government spending shocks in the data, as in the full information estimation literature (such as Leeper et al. (2010)).<sup>20</sup>

The model’s parameters are partitioned into two blocks. The first block includes a set of parameters which are calibrated. The second block includes parameters to be estimated. I estimate all the parameters of the fiscal policy rules. I also estimate the parameters of the key mechanisms in the model:  $\gamma$  governing the size of the wealth effect,  $\kappa$  determining the degree of variable capital utilisation,  $\mu$  determining the strength of the investment adjustment costs,  $\eta$  the degree of price stickiness and the habit persistence parameter  $h$ . The parameter vector to be estimated is therefore<sup>21</sup>

$$\zeta = [\phi_1 \ \phi_2 \ \theta^{gn} \ \theta^{n1} \ \theta^{n2} \ \theta^{gk} \ \theta^{k1} \ \theta^{k2} \ \eta \ \kappa \ \gamma \ h \ \mu].$$

Let the empirical impulse responses be stacked in a vector  $\bar{\mathbf{x}}$ . The model produces impulse responses conditional on a set of parameters. Let the parameter vector be  $\zeta$  as above. Let the

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<sup>20</sup>And therefore, while this paper has similarities with that literature, the goal and contribution differs.

<sup>21</sup>For a list of parameter definitions see Table 1.

output of the model given the set of parameters be  $\mathbf{x}(\zeta)$ . The objective is to choose parameters to minimize the loss function

$$\zeta = \arg \min_{\zeta} [\bar{\mathbf{x}} - \mathbf{x}(\zeta)]V^{-1}[\bar{\mathbf{x}} - \mathbf{x}(\zeta)]', \quad (36)$$

where  $V$  is a weighting matrix which includes the variances of the empirical impulses along the diagonal and zeros elsewhere. The purpose of this matrix is to down-weight observations with larger standard errors. As such, I ensure that the estimated model's responses lie as far inside the empirical confidence intervals as possible.

I match the model's impulse responses to the first 16 periods of the nine empirical impulse responses. Dropping any observation with zero variance from the loss function (the first element of the government spending series) leaves the  $\mathbf{x}$  vectors  $((9 \times 16) - 1) \times 1$  and the  $V$  matrix  $((9 \times 16) - 1) \times ((9 \times 16) - 1)$  in dimension.

The standard errors are calculated following Hall et al. (2012). Specifically the variance-covariance matrix of the estimated parameters is found as the solution to:

$$V_{\zeta} = \left[ \frac{\partial \mathbf{x}(\zeta)'}{\partial \zeta} W^{-1} \frac{\partial \mathbf{x}(\zeta)}{\partial \zeta} \right]^{-1} \quad (37)$$

where  $W$  is the variance-covariance matrix of the impulse response functions and  $\frac{\partial \mathbf{x}(\zeta)}{\partial \zeta}$  is the  $((9 \times 16) - 1) \times 9$  Jacobian of the theoretical impulse responses with respect to the parameter vector.

## 5.1 Results

The estimated parameter values are given in Table (2). The tax rate responses to the government spending shock are estimated to be small, although the response builds over time — as can be seen from the coefficients on the lagged tax rates. Figure (11) displays the matched policy responses implied by the estimated model, together with the confidence intervals from the SVAR. The estimated fiscal policy parameters in Table (2) generate responses within the empirical confidence intervals and are thus a decent replication of the empirical policy responses. I also plot the simulated debt path from the model given the spending and tax rate changes. Interestingly, based on the model's estimated parameters, these tax rate changes are also consistent with the

empirically estimated response of debt from Section 2. This reaffirms that spending shocks are typically funded more through debt than through contemporaneous tax changes.

Table (2) also reports the other estimated parameter values and their standard errors. It is worth comparing these with values discussed elsewhere. King and Rebelo (1999) take  $\kappa \in [0.1, \infty]$  and the value in Table (2) is close to the value of 0.15 used by Jaimovich and Rebelo (2009).  $\eta$  is of the order of magnitude usually used in New Keynesian models and is similar to the value of 0.83 estimated by Altig et al. (2004). The estimate for  $\gamma$  implies a very small wealth effect on labor supply and not statistically significant from zero. This reinforces the results of Schmitt-Grohe and Uribe (2012).  $h$  is similar to the value of 0.7 used by Monacelli and Perotti (2009) and is a fairly standard figure found in the wider literature.

Figure (12) displays the responses of the other key macroeconomic variables. Again, the estimated model produces responses largely within the confidence intervals. It is noteworthy that the estimated model jointly replicates the output and consumption responses, which is often a problem for New Keynesian models. Although the hours response is at the upper end of the one-standard deviation error bands, most of the real wage response is well matched. The investment response continues to decline over time, although these dynamics partly reflect the investment adjustment cost mechanism used.

## 5.2 Robustness

I now examine the robustness of the parameter estimates when each of the main mechanisms discussed earlier are turned off or directly calibrated.<sup>22</sup> Table (3) displays the results.

First consider the fiscal policy parameters. Estimates of the persistence of the government spending process ( $\rho$  and  $\phi_1$ ) are very similar across all specifications. So too is the impact response of the tax rates following the spending shock ( $\theta^{gk}$  and  $\theta^{gn}$ ). The persistence coefficients in the tax rules do vary somewhat, although these estimates still produce impulse responses within the empirical confidence intervals.

In all cases the strength of the wealth effect on labor supply is estimated to be low. This mirrors findings by Schmitt-Grohe and Uribe (2012). Furthermore, note that the loss increases

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<sup>22</sup>Parameter values used in Table (3) reflect commonly chosen values elsewhere in the literature.

significantly when  $\gamma$  is forced to be one, the case of King-Plosser-Rebelo-type preferences. The degree of price stickiness is estimated to be high across all specifications, suggesting an important role for short-run demand effects. However, when other mechanisms are turned off — notably variable capital utilisation — the degree of price stickiness becomes implausibly high. It is also interesting to note that the flexible price model (where  $\eta = 0$ ) does not perform too badly (in terms of loss). This, however, relies on an implausibly high level of variable capital utilisation and strong habit persistence. Similarly, estimates of the habit persistence parameter increase significantly when sticky prices or variable capital utilisation are turned off. In general, when turning off particular mechanisms in the model, the parameter estimates governing variable capital utilisation and the investment adjustment costs,  $\kappa$  and  $\mu$ , become very low. This suggests that the mechanisms employed in the model are all jointly important in explaining the dynamics of the macroeconomy following a shock to government spending.

These exercises confirm several important results. Firstly, that the strength of wealth effect on labor supply is robustly low across all specifications. Secondly, that the strength of the tax rate response to government spending shocks is consistently limited, so spending shocks are largely debt financed in the short term. And, thirdly, all the model's mechanisms appear important for matching the empirical evidence with familiar parameter values: the baseline case achieves the smallest loss.

## 6 Conclusion

This paper has examined the transmission mechanisms of fiscal policy and whether a relatively standard New Keynesian DSGE model can explain the empirical evidence for reasonable parameter values. In particular I focused on the role of financing and the wealth effect channel.

This paper has shown that the mix of policy instruments matters greatly for the sign and magnitude of key responses. For example, greater use of labor income taxes causes a contraction in output, consumption, the real wage and hours, all contrary to the empirical evidence presented in Section 2. Furthermore, when only part of the spending increase is financed by distortionary taxes on impact, the wealth effect on labor supply can still play a critical role in boosting

output. Without an a priori reason to calibrate these features of the model in a particular way, this paper has empirically investigated the importance of the endogenous tax and debt response and the strength of the wealth effect channel in the United States.

A number of transmission mechanisms are found to be important for allowing the estimated model to replicate the empirical responses. First, the wealth effect on labor supply is estimated to be small. This casts doubt on whether a plain vanilla neoclassical model would be able to replicate the empirical evidence. Second, sticky prices, variable capital utilisation, investment adjustment costs and habits were all found to play a key role, with parameter values in line with those found in the wider literature. Third, I find that while distortionary tax rates rise following the spending shock, their magnitudes are modest. Importantly, capital tax rates increase more than labor tax rates, limiting the contractionary effect on output and consumption in the short run. The model implies a realistic debt path on the basis of these tax rate changes. All these results imply that the debt-financed nature of the spending increase is important in explaining the expansionary effects, although these expansionary effects do not depend on the wealth effect channel, but rather the presence of sticky prices.

This paper has focused on the shorter-term effects of a shock to government spending. To the extent that nominal rigidities allow for short-run demand effects and, to the extent that the wealth effect on labor supply is small, my results suggest that debt-financed government spending shocks will stimulate output, consumption, hours and the real wage over the short term. However, as pointed out by Drautzburg and Uhlig (2013), spending increases ultimately need to be financed and the tax increases required place a welfare cost on the economy. Any short-term benefits of a stimulus to GDP or consumption therefore need to be traded-off against the long-term, and welfare, costs. Striking this balance clearly remains hugely topical in the current climate.

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## 7 Tables and Figures

Table 1: Baseline calibration

Parameter	Value	Description
$\beta$	0.99	Discount factor
$\alpha$	0.3	Capital share
$\delta$	0.025	Steady state depreciation
$\tau^K$	0	Steady state capital tax rate (from sample)
$\tau^N$	0	Steady state labor tax rate (from sample)
$N$	0.3	Steady state labor
$\frac{G}{Y}$	0.2	Steady state share of government spending
$\frac{B}{Y}$	1.6	Steady state debt to GDP ratio (quarterly)
$\sigma$	1	Inverse of elasticity of intertemporal substitution ( $\gamma = 1$ )
$\xi$	1.8	Parameter governing Frisch elasticity of labor supply ( $\gamma = 0$ )
$\phi_\pi$	1.5	Coefficient on inflation in the monetary policy rule
$\rho$	0.8	Autoregressive parameter on $a_t$ shock
$\eta$	0.75	Probability of having a fixed price
$\kappa$	0.15	Parameter governing capital utilisation
$\mu$	1/3	Parameter governing the investment adjustment costs
$\gamma$	0.01	Parameter governing the wealth effect
$h$	0.5	Parameter governing habit persistence

Table 2: Estimated parameter values

Parameter	Estimation	Description
$\rho$	0.94 (0.02)	Persistence of shock process
$\phi_1$	0.00 (0.08)	Persistence of spending process
$\phi_2$	-0.14 (0.06)	Effect of shock on spending
$\theta^{gn}$	0.0043 (0.02)	Contemporaneous response of the labor tax rate
$\theta^{gk}$	0.0046 (0.002)	Contemporaneous response of the capital tax rate
$\theta^{\tau^{N,1}}$	0.19 (0.1)	Labor tax rate AR(1) coefficient
$\theta^{\tau^{K,1}}$	1.87 (0.07)	Capital tax rate AR(1) coefficient
$\theta^{\tau^{N,2}}$	0.038 (0.1)	Labor tax rate AR(2) coefficient
$\theta^{\tau^{K,2}}$	-0.91 (0.07)	Capital tax rate AR(2) coefficient
$\gamma$	0.0023 (0.003)	Strength of the wealth effect
$h$	0.58 (0.06)	Strength of habits
$\eta$	0.86 (0.04)	Probability of a fixed price
$\kappa$	0.16 (0.33)	Governs capital utilisation
$\mu$	0.032 (0.03)	Governs investment adjustment costs
Loss	51.52	

Table 4: Data sources

Series	Source	Description
Gov. spending	BEA	Gov. cons. expenditures and gross inv. (CVM)
Capital taxes	BEA	Constructed as above
Labor taxes	BEA	Constructed as above
Output	BEA	Gross domestic product (CVM)
Real wage	BLS	BLS Series ID: PRS85006153
Hours	Unpublished BLS	Francis-Ramey “Measures of Hours per Capita”
Consumption	BEA	Personal consumption expenditures (CVM)
Investment	BEA	Gross private domestic investment (CVM)
Debt	Treasury Bulletin	Close to ‘Debt Held by the Public’

Table 3: Robustness

	$\rho$	$\phi_1$	$\phi_2$	$\theta^{gn}$	$\theta^{gk}$	$\theta^{\tau, N, 1}$	$\theta^{\tau, \kappa, 1}$	$\theta^{\tau, N, 2}$	$\theta^{\tau, \kappa, 2}$	$\gamma$	$h$	$\eta$	$\kappa$	$\mu$	Loss
Baseline	0.94 (0.02)	0.00 (0.08)	-0.14 (0.06)	0.0043 (0.02)	0.0046 (0.002)	0.19 (0.1)	1.87 (0.07)	0.038 (0.1)	-0.91 (0.07)	0.0023 (0.003)	0.58 (0.06)	0.86 (0.04)	0.16 (0.3)	0.032 (0.03)	51.52
Fixed habits ( $h = 0.6$ )	0.92 (0.02)	0.0003 (0.07)	-0.010 (0.06)	0.0021 (0.02)	0.0034 (0.002)	0.077 (0.1)	1.94 (0.07)	-0.093 (0.1)	-0.97 (0.07)	0.027 (0.01)	-	0.88 (0.03)	0.00 (0.03)	0.050 (0.05)	60.25
No habits ( $h = 0$ )	0.93 (0.01)	0.0002 (0.06)	-0.012 (0.05)	0.021 (0.02)	0.039 (0.01)	0.012 (0.07)	-0.063 (0.06)	-0.041 (0.07)	0.81 (0.07)	0.0042 (0.01)	-	0.91 (0.02)	0.00 (0.08)	0.0019 (0.02)	96.04
Fixed utilisation ( $\kappa = 0.15$ )	0.92 (0.02)	0.0024 (0.07)	-0.014 (0.06)	0.013 (0.02)	0.0043 (0.002)	0.029 (0.1)	1.89 (0.06)	0.16 (0.1)	-0.93 (0.07)	0.0044 (0.004)	0.55 (0.04)	0.85 (0.03)	-	0.029 (0.03)	56.16
No utilisation ( $\kappa = \infty$ )	0.93 (0.01)	0.011 (0.07)	-0.10 (0.05)	0.025 (0.01)	0.0016 (0.001)	0.054 (0.005)	2.00 (0.001)	0.0090 (0.002)	-1.00 (0.001)	0.069 (0.0002)	0.94 (0.0005)	0.97 (0.007)	-	0.014 (0.009)	80.29
Fixed adj. costs ( $\mu = 1/3$ )	0.93 (0.01)	0.00 (0.07)	-0.042 (0.05)	0.030 (0.02)	0.0027 (0.001)	-0.34 (0.07)	1.97 (0.09)	0.35 (0.08)	-1.00 (0.09)	0.041 (0.02)	0.86 (0.07)	0.97 (0.08)	0.087 (0.09)	-	54.96
Fixed $\eta$ $\eta = 0.75$	0.92 (0.02)	0.00 (0.07)	0.0094 (0.05)	0.010 (0.02)	0.026 (0.01)	-0.10 (0.08)	-0.020 (0.04)	0.20 (0.06)	0.93 (0.08)	0.061 (0.02)	0.89 (0.03)	-	0.0024 (0.04)	0.0077 (0.007)	60.64
Flexible prices ( $\eta = 0$ )	0.92 (0.02)	0.0016 (0.07)	0.016 (0.06)	0.027 (0.02)	0.022 (0.01)	0.012 (0.1)	0.042 (0.03)	-0.021 (0.1)	0.92 (0.09)	0.061 (0.02)	0.88 (0.05)	-	0.00 (0.04)	0.010 (0.008)	64.93
Fixed $\gamma$ $\gamma = 0.01$	0.92 (0.02)	0.00 (0.07)	-0.024 (0.06)	0.0054 (0.02)	0.0036 (0.001)	0.076 (0.1)	1.91 (0.06)	0.0051 (0.1)	-0.94 (0.06)	-	0.56 (0.08)	0.87 (0.03)	0.00 (0.05)	0.032 (0.03)	53.98
$\gamma = 1$	0.91 (0.01)	0.00 (0.07)	0.041 (0.06)	0.024 (0.02)	0.0023 (0.001)	0.026 (0.2)	1.97 (0.06)	0.14 (0.2)	-1.0 (0.06)	-	0.18 (0.3)	0.92 (0.02)	0.00 (0.04)	0.11 (0.2)	125.42

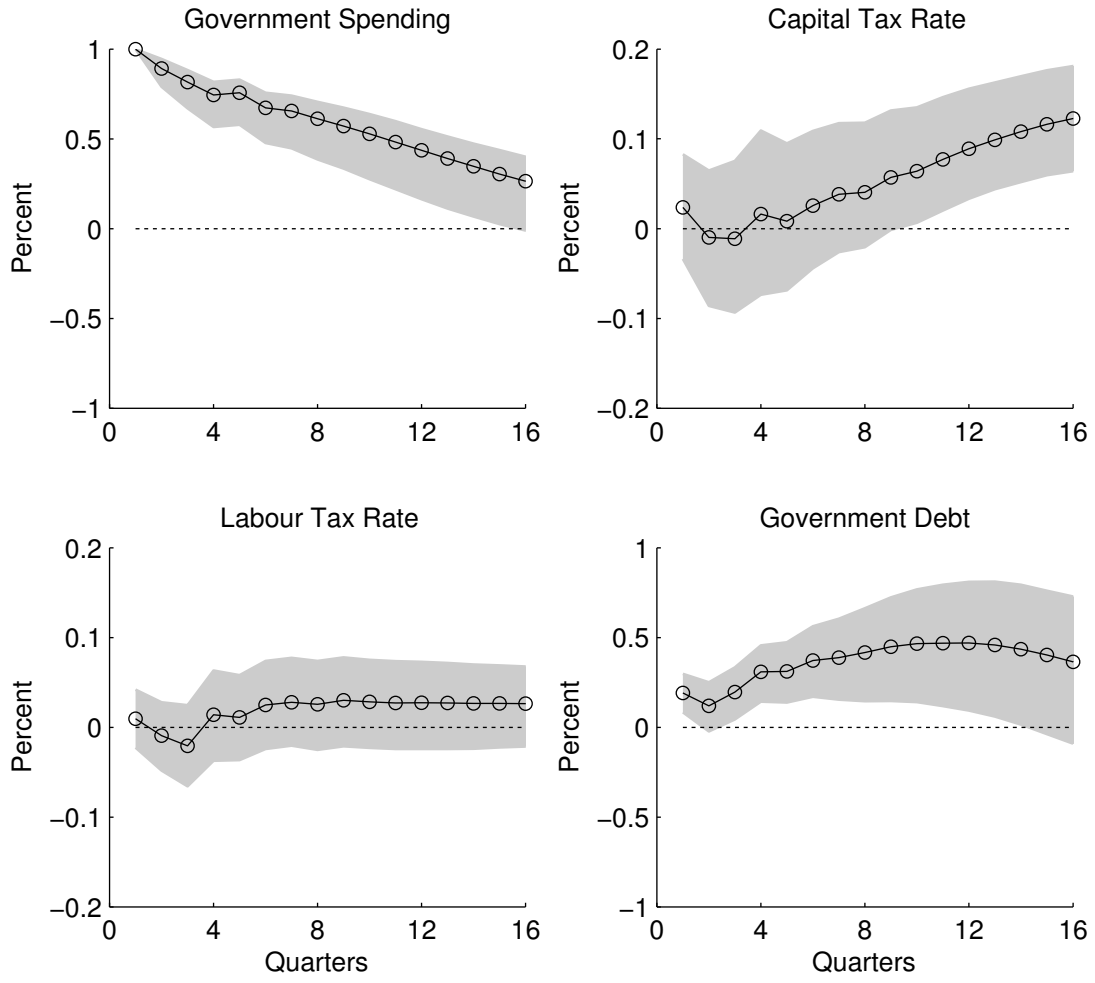


Figure 1: *Impulse responses for the fiscal policy variables*

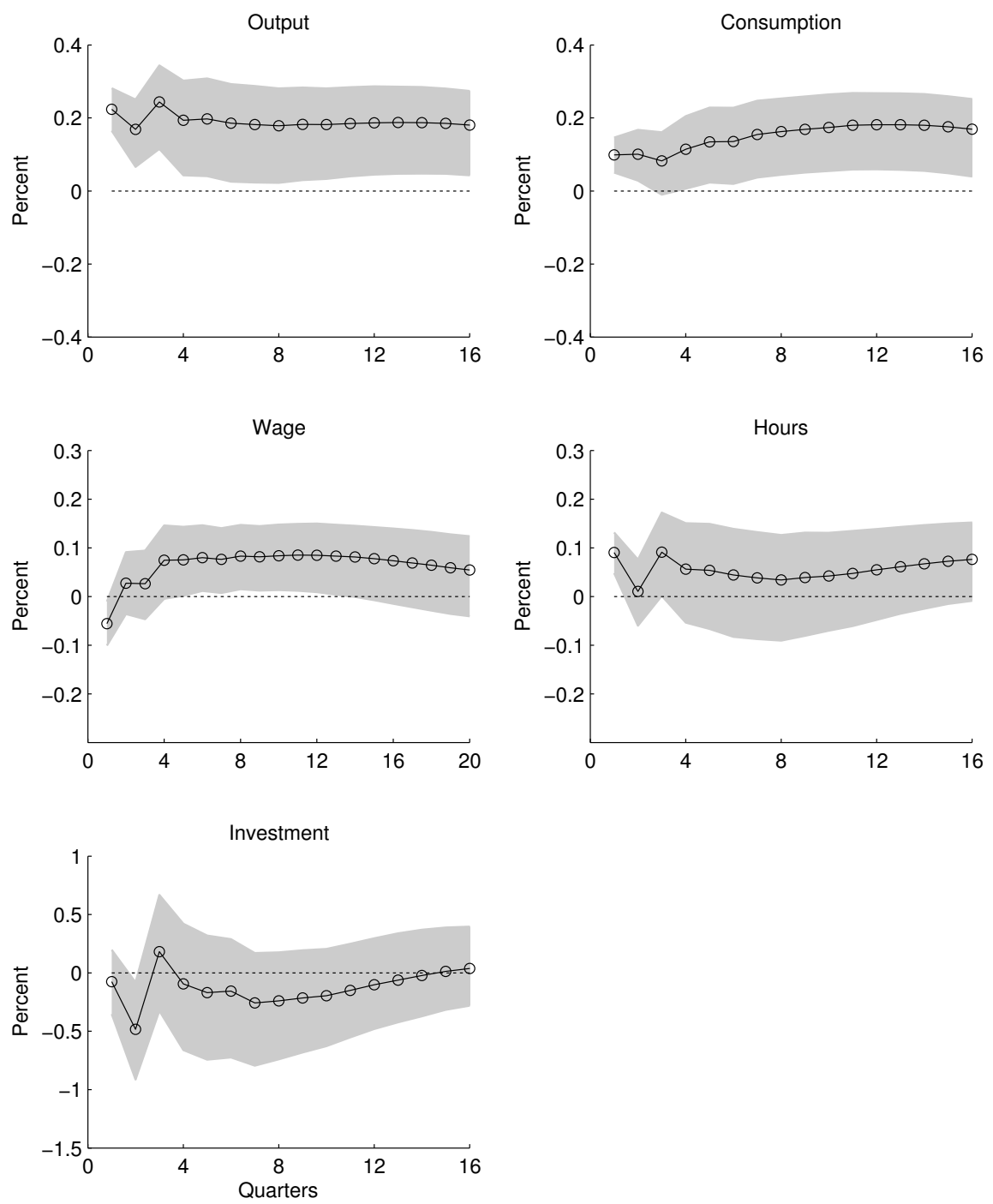


Figure 2: *Impulse responses for key macroeconomic variables*

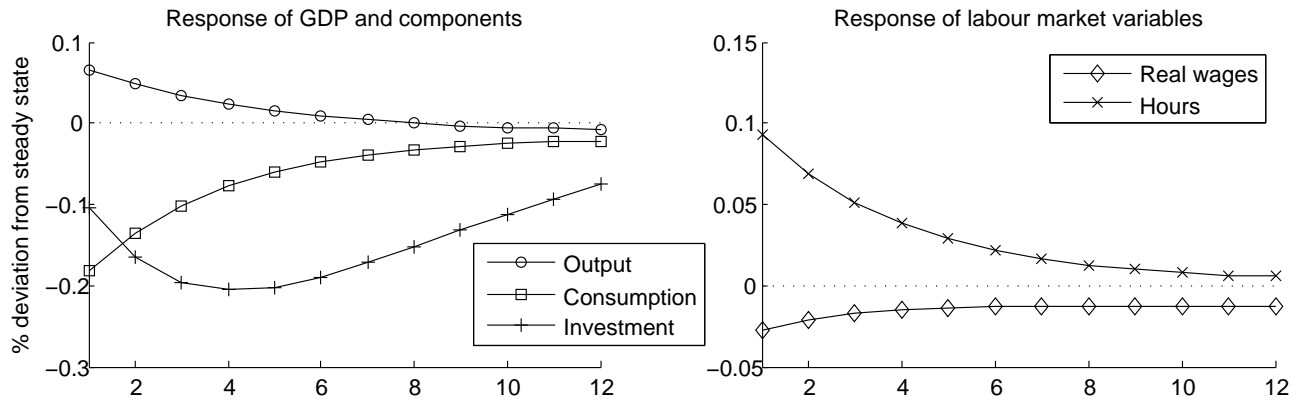


Figure 3: A simple Neoclassical model:  $\eta = 0$ ,  $\gamma = 1$ ,  $\kappa = \infty$ ,  $h = 0$

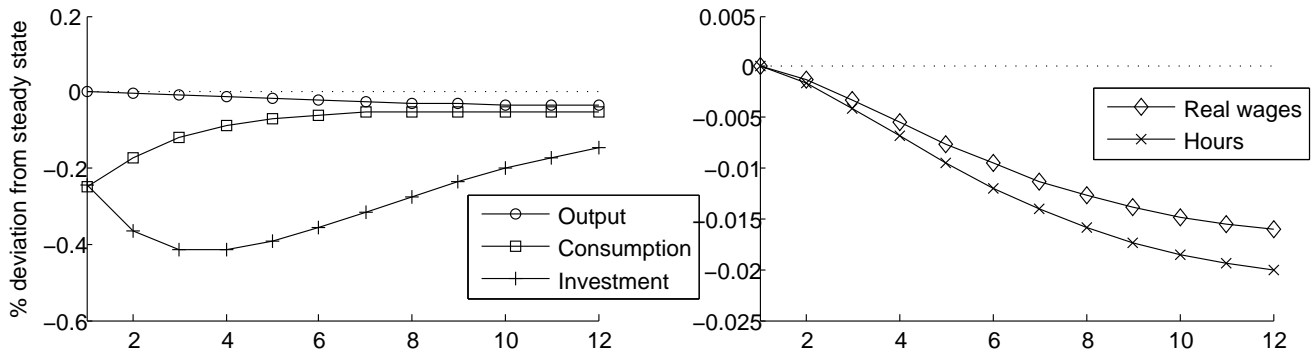


Figure 4: A simple Neoclassical model (but no wealth effect):  $\eta = 0$ ,  $\gamma = 0$ ,  $\kappa = \infty$ ,  $h = 0$

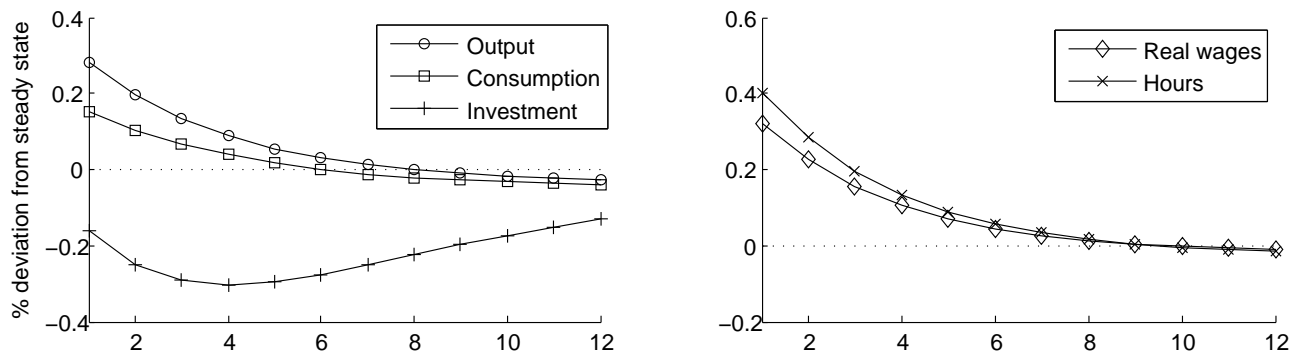


Figure 5: Including sticky prices:  $\eta = 0.7$



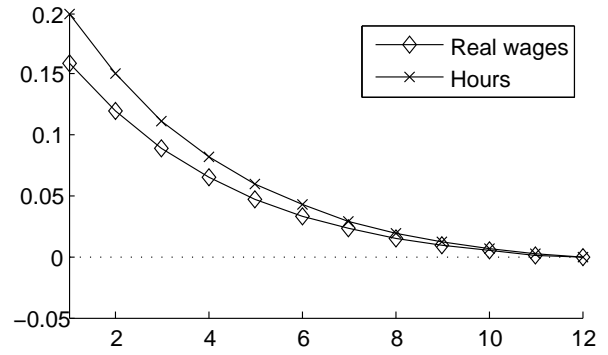
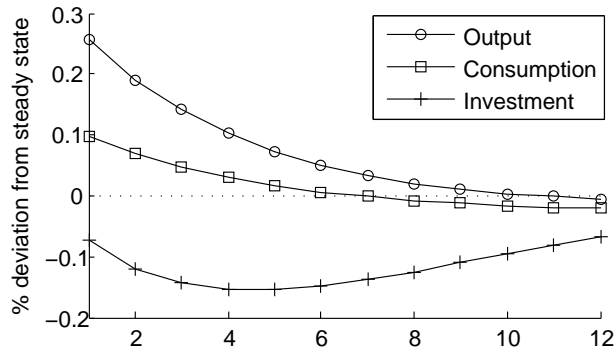


Figure 6: Including variable capital utilization:  $\kappa = 0.15$

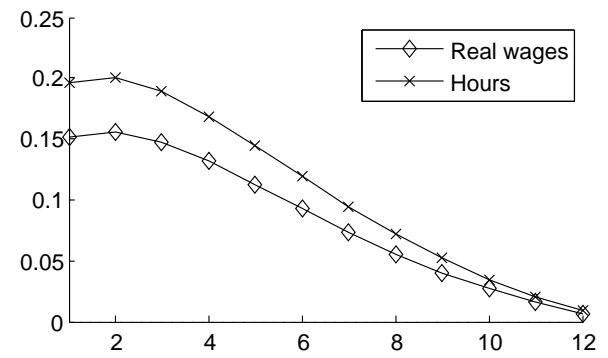
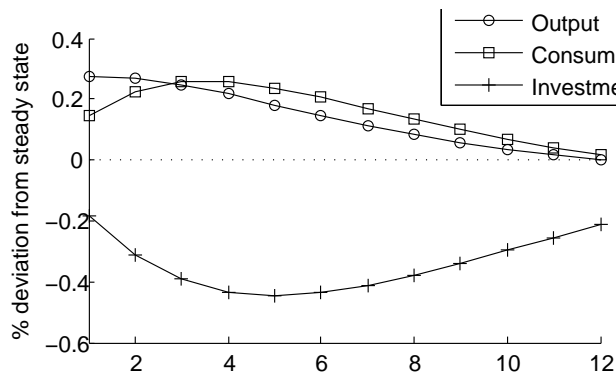


Figure 7: The full (lump sum tax) model: including habits:  $h = 0.5$

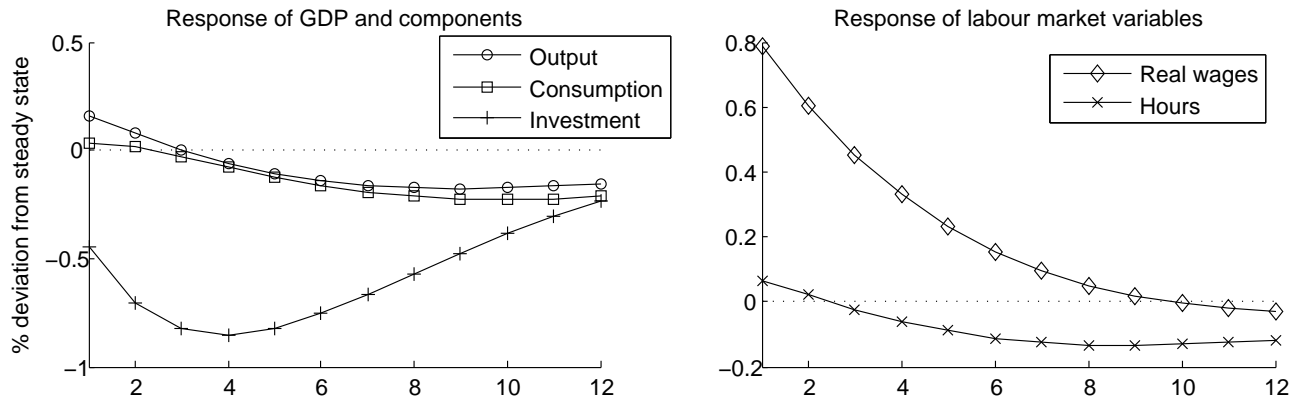


Figure 8: *Distortionary labor and capital tax rates respond*

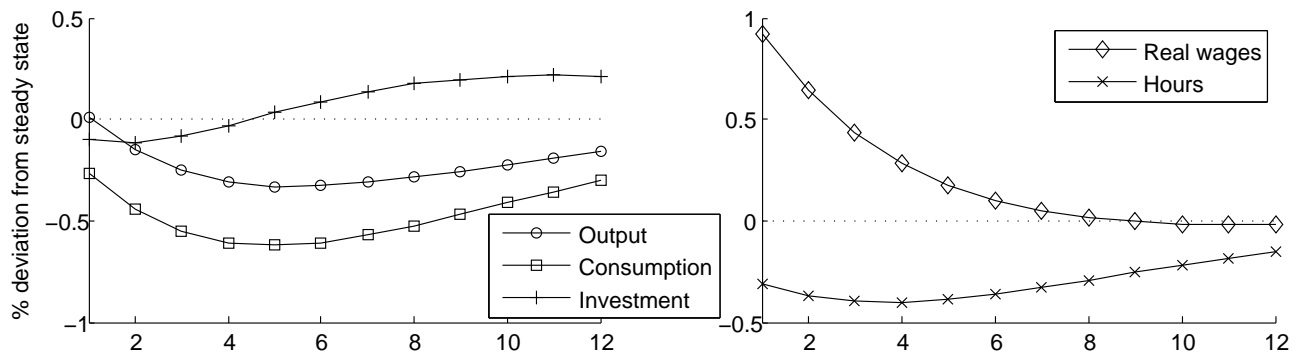


Figure 9: *Only the labor income tax rate responds*

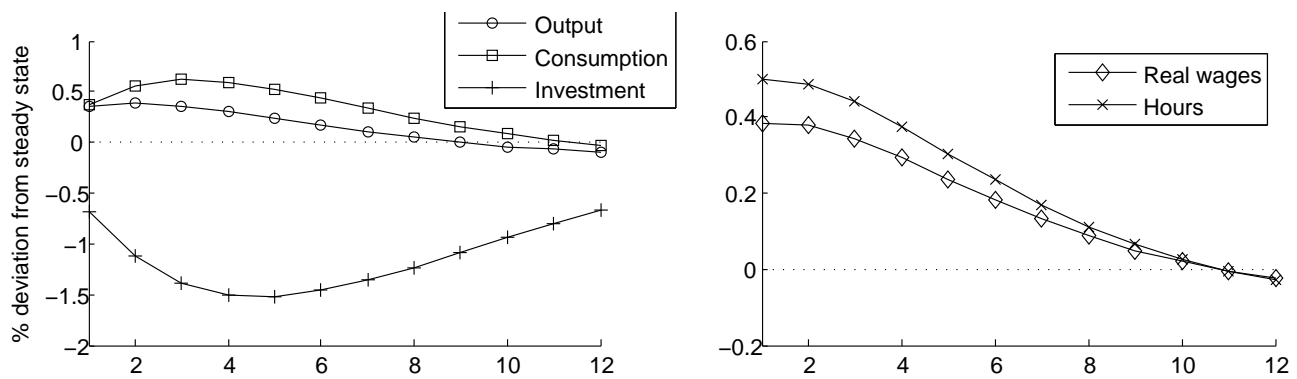


Figure 10: *Only the capital tax rate responds*

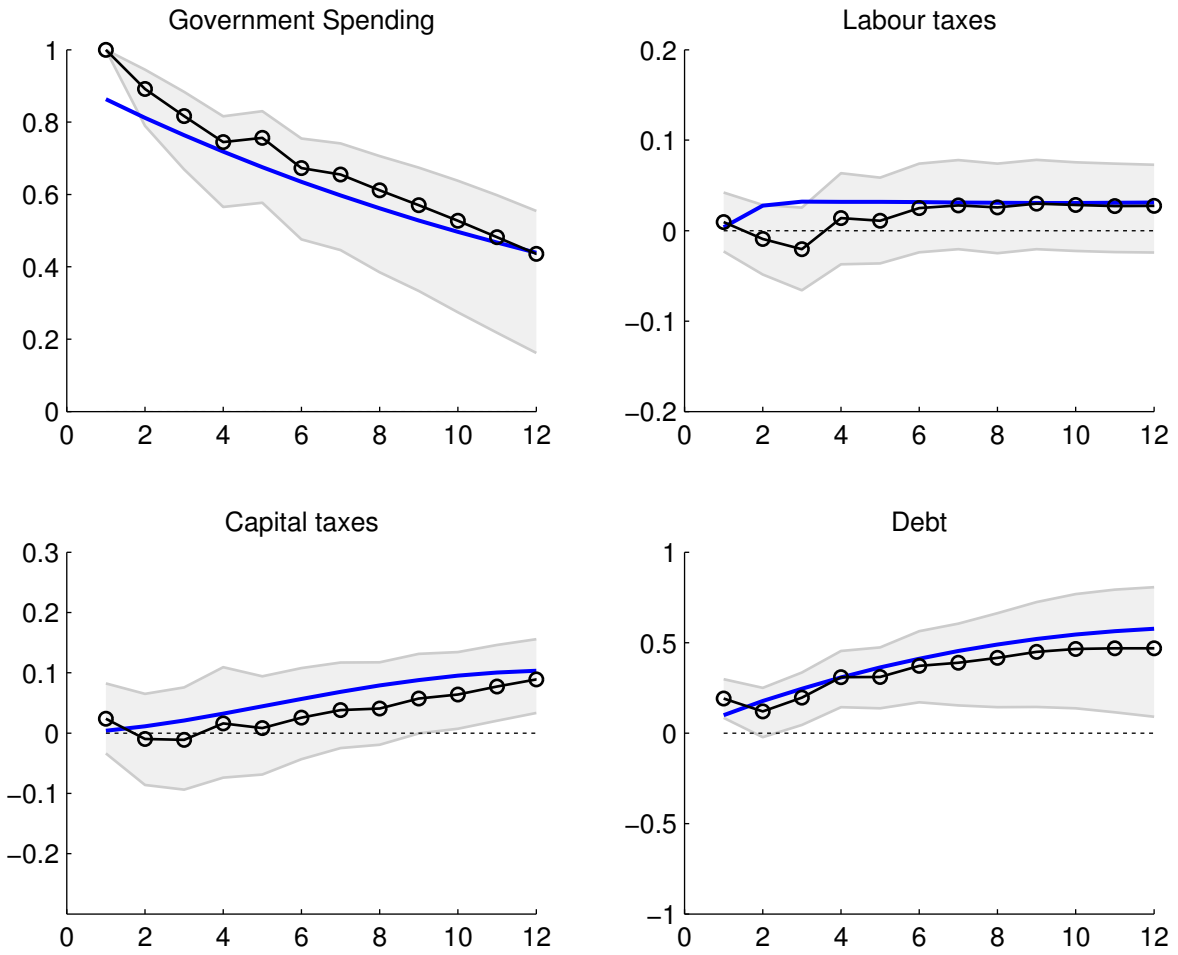


Figure 11: Responses of the fiscal variables given the parameter estimates

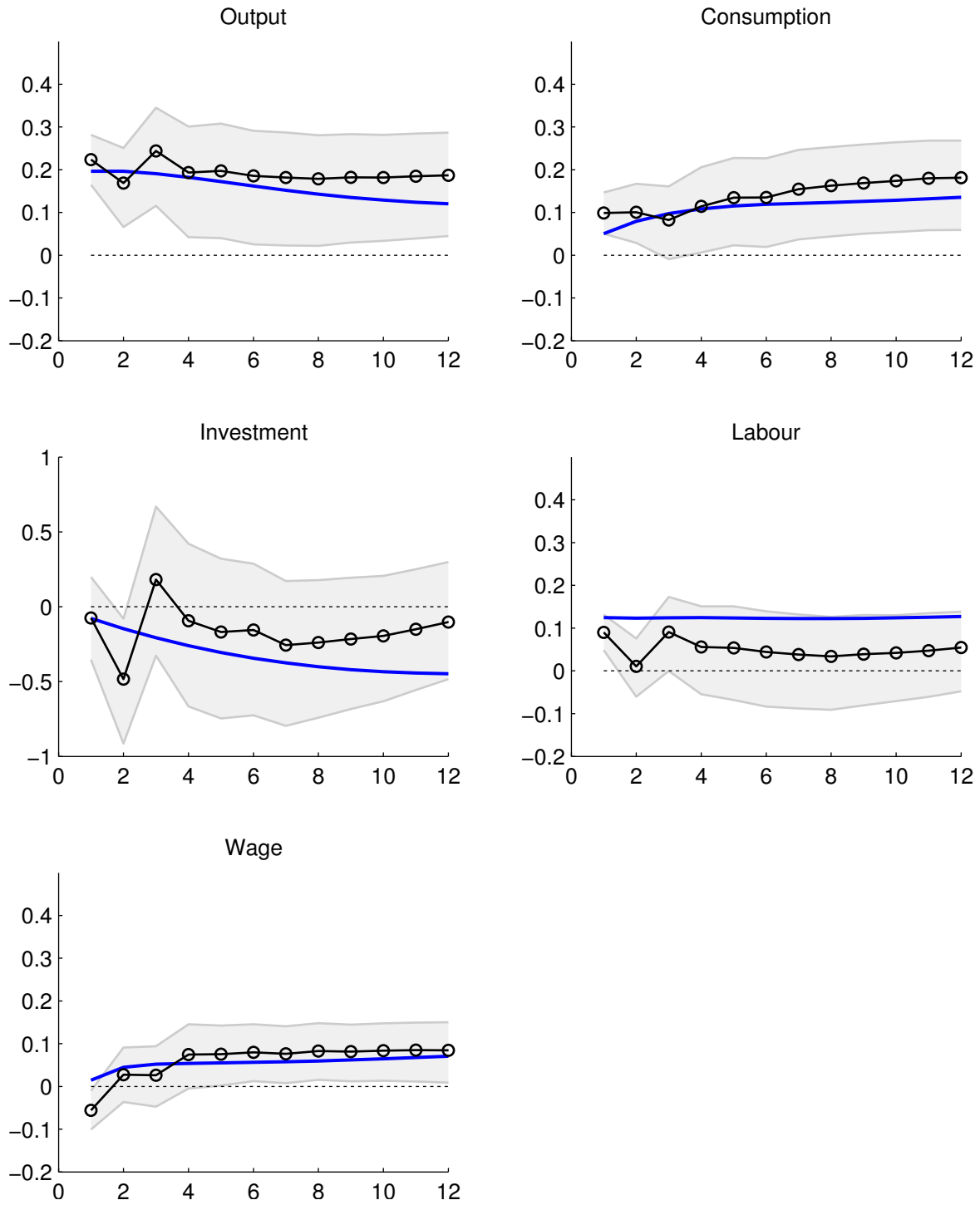


Figure 12: Responses of the other variables given the parameter estimates

# Appendices

## A Data Appendix

The data span the period 1955:1 to 2007:4 and the variable definitions keep close Blanchard and Perotti (2002), where relevant. Real government spending, real consumption, real investment and real GDP come directly from the Bureau of Economic Analysis NIPA tables. All variables are the log of real per capita variables. Nominal variables are deflated by their own implicit price deflators with the exception of government spending which is deflated by the GDP deflator. Real hours are an unpublished Bureau of Labor Statistics (BLS) series, downloadable from Valerie Ramey's website. The real wage is real hourly compensation, non-farm business, in logs from the BLS. Population is total civilian population also from the BLS.

Real per capita debt is the log of my constructed debt measure divided by the total population and the GDP deflator. The debt measure is very close the 'Debt Held by the Public'. This series is only available from 1970, so I construct a proxy from old editions of the United States Treasury Bulletin back to 1947. For the pre-1974 period this is the 'Total Public Issues' series. After 1974, for consistency, I have to construct the 'Total Public Issues' series from the Monthly Statement of Public Debt by combining 'Total Interest Bearing Debt' minus the 'Government Accounts Series' plus 'Total Treasury Deposit Funds'. Because this is not an exact match to 'Debt Held by the Public' I check how close the two measures are (for the common part of the series, 1970 onwards) — the R squared is 0.999, so I am confident that my constructed series reflects changes in 'Debt Held By the Public'.

The capital and labor income tax rates are constructed following Jones (2002), which in turn is related to Mendoza et al. (1994). I reconstruct the series, extend it back to 1947 following Burnside et al. (2004) and forward to 2008. As a check, I reproduce the narrative Vector Autoregression results in Burnside et al. (2004), the results are very similar. These extra results are available on request.

## B Linearized models

### B.1 Notation

Lower case letters represent the percentage deviation of each variable from its steady state value. The only exceptions are the tax rates  $\tau_t^N$  and  $\tau_t^K$  which are expressed as percentage point deviations to match the variable definition in the VAR.

### B.2 The consumer's conditions

#### B.2.1 Households

$$a_1c_t + a_2n_t + a_3x_t + a_4x_{t-1} + a_5\mu_t - a_6\lambda_t + a_7c_{t-1} = 0 \quad (38)$$

$$\lambda_t + w_t - \frac{1}{1 - \tau^N} \tau_t^N = b_1c_t + b_2n_t + b_3x_t + b_4c_{t-1} \quad (39)$$

$$c_1c_t + c_2n_t + c_3x_t + c_6c_{t-1} + \mu\mu_t = c_4\mu_{t+1} + c_5c_{t+1} \quad (40)$$

$$\mathbb{E}_t\lambda_{t+1} = \lambda_t - r_t \quad (41)$$

$$(1 - h)x_t = (1 - h)(1 - \gamma)x_{t-1} + \gamma c_t - h\gamma c_{t-1} \quad (42)$$

$$\mu q_t - (1 + \beta)i_t + i_{t-1} - \beta\mathbb{E}_t i_{t+1} = 0 \quad (43)$$

where  $\mu = \frac{1}{\phi''}$ .

$$q_t + r_t = r^K(1 - \tau^K)\beta\mathbb{E}_t r_{t+1}^K - \beta r^K\mathbb{E}_t \tau_{t+1}^K + \beta(1 - \delta)\mathbb{E}_t q_{t+1} - \beta\delta'(z)z\mathbb{E}_t z_{t+1} \quad (44)$$

where the coefficients are given at the end of this appendix.

### B.3 Firms

Up to a first order approximation the aggregate production function is given by

$$y_t = \alpha z_t + \alpha k_t + (1 - \alpha)n_t \quad (45)$$

and factors are paid

$$r_t^K = mc_t + y_t - k_t \quad (46)$$

$$w_t = mc_t + y_t - n_t. \quad (47)$$

Utilisation is described by

$$(1 + \kappa)z_t = y_t - k_t - q_t + mc_t - \frac{1}{1 - \tau^K} \tau_t^K \quad (48)$$

where  $\xi = \frac{\delta''}{\delta}$ . Price evolution is determined by the New Keynesian Phillips Curve

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \frac{(1 - \eta)(1 - \beta\eta)}{\eta} mc_t. \quad (49)$$

## B.4 Policy rules

$$r_t - \mathbb{E}_t \pi_{t+1} = \phi_\pi \pi_t \quad (50)$$

$$\tau_t^n = \theta^{gn} g_t + \theta^{bn} b_t + \theta^{n1} \tau_{t-1}^n + \theta^{n2} \tau_{t-2}^n \quad (51)$$

$$\tau_t^k = \theta^{gk} g_t + \theta^{bk} b_t + \theta^{k1} \tau_{t-1}^k + \theta^{k2} \tau_{t-2}^k \quad (52)$$

$$g_t = \phi_1 g_{t-1} + \phi_2 a_t \quad (53)$$

$$\frac{T}{Y} \hat{T}_t = \frac{B}{Y} \frac{1}{R} (b_{t+1} + r_t) - \frac{B}{Y} b_t = \frac{G}{Y} g_t - (1 - \alpha) \tau^n (\tau_t^n + n_t + w_t) - \alpha \tau^k (\tau_t^k + r_t^k + k_t). \quad (54)$$

## B.5 Identities

$$\delta i_t = k_{t+1} - (1 - \delta) k_t \quad (55)$$

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{G}{Y} g_t. \quad (56)$$

## B.6 Stochastic processes

$$a_{t+1} = \rho a_t + \epsilon_{t+1} \quad (57)$$

## B.7 Coefficients from the linearized Jaimovich–Rebelo preferences

$$a_1 = (\gamma - 1) \mu \gamma X^{1-\gamma} (C(1-h))^{\gamma-2} C - \sigma C \chi (C - hC - \psi N^\xi X)^{-1}$$

$$a_2 = \xi \psi N^\xi X \sigma (C - hC - \psi N^\xi X)^{-\sigma-1}$$

$$a_3 = \psi N^\xi X \sigma (C - hC - \psi N^\xi X)^{-\sigma-1}$$

$$a_4 = (1 - \gamma)\mu\gamma X^{1-\gamma}(C(1 - h))^{\gamma-1}$$

$$a_5 = \mu\gamma X^{1-\gamma}(C(1 - h))^{\gamma-1}$$

$$a_6 = \mu\gamma X^{1-\gamma}(C(1 - h))^{\gamma-1} + \chi$$

$$a_7 = -ha_1$$

$$b_1 = -(\sigma\psi N^{\xi-1}\xi X((C - hC - \psi N^\xi X)^{-\sigma-1})C)/(a_6 W(1 - \tau^N))$$

$$b_2 = ((\xi - 1)\psi X N^{\xi-1}\xi\chi + \sigma\psi^2 N^{2\xi-1}\xi^2 X^2(C - hC - \psi N^\xi X)^{-\sigma-1})/(a_6 W(1 - \tau^N))$$

$$b_3 = X(\psi N^{\xi-1}\xi\chi + \psi N^{\xi-1}\xi X(\sigma((C - hC - \psi N^\xi X)^{-\sigma-1})\psi N^\xi))/(a_6 W(1 - \tau^N))$$

$$b_4 = -hb_1$$

$$c_1 = -\sigma\psi N^\xi(C - hC - \psi N^\xi X)^{-\sigma-1}C + h(1 - \gamma)\mu\beta\gamma(C(1 - h))^{\gamma-1}X^{-\gamma}C$$

$$c_2 = \psi^2\xi X\sigma N^{2\xi}(C - hC - \psi N^\xi X)^{-\sigma-1} + \xi\psi N^\xi\chi$$

$$c_3 = \sigma\psi^2 N^{2\xi}(C - hC - \psi N^\xi X)^{-\sigma-1}X + \gamma\mu\beta(1 - \gamma)(C(1 - h))^\gamma X^{-\gamma}$$

$$c_4 = \mu\beta(1 - \gamma)(C(1 - h))^\gamma X^{-\gamma}$$

$$c_5 = \gamma\mu\beta(1 - \gamma)(C(1 - h))^{\gamma-1}X^{-\gamma}C$$

$$c_6 = \sigma h\psi N^\xi(C - hC - \psi N^\xi X)^{-\sigma-1}C$$

$$\chi = (C - hC - \psi N^\xi X)^{-\sigma}$$

## C Steady state

Our assumptions of  $\phi(I/K)$  imply that

$$\frac{I}{K} = \delta$$

therefore

$$\frac{I}{Y} = \frac{I}{K} \frac{K}{Y} = \delta \frac{K}{Y}.$$



Given the tax and subsidy on revenue ( $mc = 1$ ), the state version of the return on capital implies

$$r^K = \alpha \frac{Y}{K}.$$

From equation (12)

$$r^K = \frac{R - 1 + \delta}{1 - \tau^K} \quad (58)$$

therefore

$$\frac{K}{Y} = \frac{\alpha}{r^K} \quad (59)$$

and

$$\frac{I}{Y} = \frac{\delta \alpha}{r^K}. \quad (60)$$

The share of consumption can be written

$$\frac{C}{Y} = 1 - \delta \frac{K}{Y} - \frac{G}{Y}, \quad (61)$$

This follows from the resource constraint, equation (21).  $\psi$  can be found by solving the household's steady state first order conditions

$$\psi = \left( N^\xi \left[ \frac{\xi X}{W(1 - \tau^N)N} - \frac{\gamma X^{1-\gamma} (C(1-h))^{\gamma-1}}{\beta(1-\gamma)(C(1-h))^\gamma X^{-\gamma} - 1} \right] \right)^{-1} \quad (62)$$

where  $N$  is steady state hours and is calibrated. From the production function and the marginal product of capital is

$$K = \left( \frac{r^K}{\alpha} \right)^{\left( \frac{1}{\alpha-1} \right)} N, \quad (63)$$

and dividing the resource constraint by  $K$  gives an expression for  $CK$ . Using this together with equation (63) yields an expression for steady state consumption. The steady state real wage follows from

$$W = (1 - \alpha) \left( \frac{K}{N} \right)^\alpha. \quad (64)$$

$\mu$  is the steady state Lagrange multiplier

$$\mu = \frac{\psi N^\xi \chi}{\beta(1-\gamma)(C(1-h))^\gamma X^{-\gamma} - 1}. \quad (65)$$

From equation (6), steady state  $X$  is given by:

$$X = C(1 - h). \quad (66)$$

The steady state gross real interest rate is related to the discount factor

$$R = \frac{1}{\beta}. \quad (67)$$

From the first order condition for  $z_t$

$$\delta'(z)z = (1 - \tau^K)\alpha\frac{Y}{K}. \quad (68)$$

$\frac{B}{Y}$  is calibrated.

# D More general policy rules

