The Output and Welfare Effects of Government Spending Shocks over the Business Cycle*

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Abstract

This paper studies the output and welfare effects of shocks to government expenditure in a canonical medium scale DSGE model. Our model considers both government consumption and investment, and allows for a variety of fiscal financing mechanisms. The usefulness of government expenditure is modeled by assuming that government consumption enters the utility function in a non-separable way with private consumption and that government capital enters the aggregate production function. We use the model to address several questions pertaining to the magnitude and state-dependence of both the output and welfare effects of changes in government expenditure. Relative to what is observed in the data, under our baseline parameterization it would be optimal to reduce the average size of government consumption (relative to total output) and increase the average size of government investment. Countercyclical government expenditure is undesirable as a general policy proscription, but we also highlight situations (such as when monetary policy is passive) in which it might be beneficial.

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1 Introduction

The recent Great Recession has led to renewed interest in fiscal stimulus as a tool to fight recessions. There nevertheless seems to be a lack of consensus concerning some fundamental questions. How large is the government spending multiplier? Does it vary in magnitude over the business cycle? What are the welfare implications of government spending shocks? Is countercyclical government spending desirable? This paper seeks to provide some answers to these questions.

We study the effects of government spending shocks in an estimated medium-scale New Keynesian DSGE model along the lines of Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). The core of our model is similar to the models in these papers, with price and wage stickiness, capital accumulation, several sources of real inertia, and a number of shocks. To that core we add two different kinds of government spending. Government consumption enters the model in a conventional way as another aggregate expenditure category. The usefulness of government consumption is modeled by assuming that households receive a utility flow from it. Our utility specification permits private and government consumption to be complements (or substitutes). Government investment also enters the model as an additional expenditure category, but contributes to private productivity as government capital is assumed to be an argument in the aggregate production function, in a way similar to how government investment is modeled in Baxter and King (1993). Our model allows for a rich fiscal financing structure, wherein government expenditure can be financed via a mix of lump sum taxes, debt, and distortionary taxes. The model is estimated using Bayesian methods on US data.

Our paper departs from the existing literature on two key dimensions. First, we solve the model via a higher order perturbation (in particular, a third order approximation about the non-stochastic steady state). Solving the model via a higher order approximation allows us to investigate whether there are any important state-dependent effects of changes in government consumption and investment. Second, rather than focusing solely on how changes in government expenditure affect output, we also study how changes in government spending impact a measure of aggregate welfare. In doing so, we adopt the following terminology. We define the "output multiplier" as the change in output for a one unit change in government expenditure (either government consumption or investment). This is the standard definition of a fiscal multiplier. The "welfare multiplier" is defined analogously, but examines how aggregate welfare reacts to a one unit change in government expenditure. So as to put the welfare multipliers in interpretable units, we express them in consumption equivalent terms. Studying the signs and magnitudes of the average welfare multipliers for government consumption and investment allows us to infer whether the average sizes of government consumption and investment are larger or smaller than households would prefer. Focusing on how the welfare multipliers vary across states of the business cycle allows us to draw conclusions concerning the desirability of countercyclical government expenditure.

For our baseline analysis, we assume that all government finance is through lump sum taxation. We also assume that monetary policy is characterized by an active Taylor rule. Our principal quantitative experiment involves computing output and welfare multipliers for both types of government expenditure at several thousand different realizations of the state vector. These different states are drawn by simulating the model for several thousand periods.

We find that the average output multiplier for government consumption is about 1.06. A multiplier in excess of unity is due to two features of the model – estimated complementarity between private and government consumption, and price and wage rigidity. The output multiplier is not constant across states, ranging from a low of 1 to a high 1.15. The output multiplier is mildly positively correlated with the simulated level of output. The welfare multiplier for government consumption is negative on average. It is substantially more volatile than the output multiplier. It is also strongly positively correlated with the simulated level of output. Conditional on being in simulated states which we identify as recessions, the output multiplier is about equal to its unconditional average, while the welfare multiplier is significantly lower than its unconditional mean. The average impact output multiplier for government investment is 0.90.[1] In contrast to the government consumption multiplier, the investment multiplier varies little across states and is mildly negatively correlated with output. The average welfare multiplier for government investment, in contrast to the consumption multiplier, is positive. It is uncorrelated with the simulated level of output.

The following normative conclusions can be drawn from our quantitative analysis. First, our results suggest that while the average share of total government expenditure in output is roughly optimal, households would prefer a shift away from government consumption towards government investment. We do not wish to take too strong a stand on the optimal size of government expenditure, however. For reasons detailed in Section 3.2 and Appendix C, the parameter governing the weight on government consumption and the parameter governing the productivity of government investment are poorly identified, and are hence calibrated in our analysis.[2] In robustness exercises, we show that different values of these parameters can affect the sign and magnitude of the average welfare multipliers for government consumption and investment. Second, our results cast doubt on the desirability of countercylical government expenditure as a general policy proscription. This is particularly true for government consumption, where the welfare multiplier is strongly positively correlated with simulated output. This suggests that households value additional government consumption most in periods where output is relatively high, not during times of recession. Our result concerning the positive correlation between the welfare multiplier for government consumption and output is quite robust to different values of the parameter governing the utility weight on government consumption, which affects the sign and magnitude of the average multiplier but not its correlation with simulated output. In our baseline calibration, the welfare multiplier for government

[1]While we focus on impact multipliers for output, it is important to emphasize that the benefits of government investment accrue in future, as it takes time for the stock of government capital to accumulate. Because aggregate welfare is forward-looking (the present discounted value of flow utility), the welfare multiplier for government investment can therefore be positive on average even though the average impact output multiplier for government investment is substantially smaller than for government consumption.

[2]In contrast, for a given weight on government consumption in the utility function of households, the parameter governing the degree of complementarity between government and private consumption does seem well-identified. This is consistent with the analysis in Bouakez and Rebei (2007).

investment is uncorrelated with output, suggesting that recessions are neither good nor bad times (on average) to increase government investment. This result is more sensitive to assumed parameter values. In particular, if government investment is sufficiently productive, the welfare multiplier can be negatively correlated with simulated output.

Any normative implications are of course dependent on the structural model used to draw them. We have not attempted to write down a model where counteryclical government expenditure is (or is not) desirable, nor a model which delivers large state-dependent effects of government expenditure shocks on output. Rather, we have taken a rather canonical medium-scale DSGE model and modified it so as to accommodate beneficial aspects of government expenditure in ways which seem *a priori* reasonable and which are consistent with what has been done elsewhere in the literature. A different model, or different details about the workhorse model, could deliver different results. In Section 4.3, we consider a stripped down version of the medium-scale model to try and develop some intuition for the signs, magnitudes, and state-dependence of the output and welfare multipliers for both kinds of government expenditure. This intuition may provide some insight into different model features which could deliver different normative results.

The medium scale DSGE model used for our analysis abstracts from many features which might be relevant for the effects of government expenditure shocks. We therefore consider several extensions to our baseline in analysis in Section 5. These include alternative means of fiscal finance, passive monetary policy regimes wherein the interest rate is unresponsive to changes in government expenditure for a number of periods, and a modification of the model which allows for a fraction of households to engage in "rule of thumb" behavior, simply consuming their income each period.

Our baseline assumption of lump sum finance for the government turns out to represent a "best case." When we allow steady state distortionary tax rates (on consumption, wage income, and capital income) to be positive, average output and welfare multipliers for both kinds of government expenditure are smaller. When these distortionary taxes must adjust so as to ensure non-explosive paths of government debt (rather than lump sum taxes doing the adjustment), average multipliers are even smaller. Further, when distortionary taxes adjust to government debt, the welfare multipliers for both kinds of government expenditure become more positively correlated with output. Put differently, the case for countercylical government expenditure is weaker when distortionary taxes enter the model.

Much of the renewed interest in fiscal policy has been driven by the recent period of low interest rates and the recognition that government expenditure may be substantially more effective at stimulating output when monetary policy is in a passive regime. We simulate the effects of a passive monetary policy regime by assuming that the nominal interest rate is in expectation pegged at a fixed value for known number of periods in the face of a shock to government expenditure. We find that average output multipliers for both types of government expenditure can be substantially larger when the nominal interest rate is pegged. Furthermore, we find that the output multipliers can vary significantly more across states under a peg in comparison to our baseline assumption that monetary policy follows a Taylor rule. Along with higher average output multipliers, our results indicate that the average welfare multipliers for both types of government expenditure are larger when monetary policy is passive in comparison to normal times. This finding suggests, consonant with results in the existing literature, that fiscal stimulus is relatively more attractive during periods of passive monetary policy. Furthermore, if the interest rate is pegged for a sufficiently long duration, the welfare multipliers for both types of government expenditure can become negatively correlated with output. In contrast to normal times, the case for countercyclical government expenditure is stronger when monetary policy is passive.

A final extension we consider is the inclusion of a fraction of households who do not have access to credit markets. We refer to these household as "rule of thumb" households following Galí, López-Salido and Vallés (2007). Average output multipliers for both types of government expenditure are moderately larger the higher is the fraction of rule of thumb households. Correspondingly, the average aggregate welfare multipliers for both types of government expenditure are also larger, though the correlations of the aggregate welfare multipliers with simulated output are similar to our baseline analysis.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review and discusses the ways in which our paper contributes to and expands upon the literature on fiscal multipliers. Section 3 presents and estimates a medium scale DSGE model with both government consumption and investment. Details of the model are available in Appendix A. Section 4 describes our benchmark quantitative exercises, presents our baseline results, and provides some intuition for them. Section 5 considers several extensions to our model. Section 6 concludes.

2 Related Literature

In this section, we provide a partial review of the related literature and discuss where our contributions and differences relative to that literature lie.

There exists a large empirical literature that seeks to estimate fiscal multipliers using reduced form techniques. Using orthogonality restrictions in an estimated VAR, Blanchard and Perotti (2002) identify fiscal shocks by ordering government spending first in a recursive identification. They report estimates of spending multipliers between 0.9 and 1.2. Mountford and Uhlig (2009) use sign restrictions in a VAR and find a multiplier of about 0.6. Ramey (2011) uses narrative evidence to construct a time series of government spending "news," and reports multipliers in the range of 0.6-1.2. This range aligns well with a number of papers that make use of military spending as an instrument for government spending shocks in a univariate regression framework (see, e.g. Barro 1981, Hall 1986, Hall 2009, Ramey and Shapiro 1998, Barro and Redlick 2011, and Eichenbaum and Fisher 2005). The bulk of this empirical literature suggests that the government spending multiplier is somewhere in the neighborhood of one, which aligns well with our estimate of the average government consumption multiplier of 1.06.

There is also a limited but growing literature that seeks to estimate state-dependent fiscal multipliers using reduced form econometric techniques. Auerbach and Gorodnichenko (2012) estimate a regime-switching VAR model and find that the output multiplier is highly countercyclical and can be as high as three during periods they identify as recessions. Bachmann and Sims (2012) and Mittnik and Semmler (2012) also analyze non-linear time series models and reach similar conclusions. Nakamura and Steinsson (2014) consider a regression model that allows the multiplier to vary with the level of unemployment, and find that the government spending multiplier is substantially larger when unemployment is high. Shoag (2015) also finds that the multiplier is higher when the labor market is characterized by significant slack.

Ramey and Zubairy (2014) analyze a new historical US data set and estimate a state-dependent time series model based on Jordà (2005)'s local projection method. They find limited evidence that the government spending multiplier varies significantly across states of the business cycle, in contrast to Auerbach and Gorodnichenko (2012) and the other papers cited above. One methodological point which they raise is that much of the existing empirical literature estimates the elasticity of output with respect to government spending (i.e. $\frac{d\ln Y_t}{d\ln G_t}$), and then converts this elasticity into a multiplier by multiplying the elasticity by the average ratio of output to government spending (i.e. $\frac{dY_t}{dG_t} = \frac{d\ln Y_t}{d\ln G_t}\frac{Y}{G}$). Ramey and Zubairy (2014) argue that this approach is likely to make the estimated multiplier artificially high in periods in which output is low because the actual ratio of output to government spending is quite procyclical. Our analysis suggests that this criticism might be quantitatively important. When we compute output multipliers for government consumption in our model by first computing an elasticity and then converting it into levels using the average output to government spending ratio, we find that the incorrectly computed output multiplier is more than twice as volatile across states as the actual output multiplier and is strongly countercylical, whereas the actual output multiplier is mildly procyclical.

Another strand of the literature examines the magnitude of fiscal multipliers within the context of DSGE models. Baxter and King (1993) is an early and influential contribution. Their model, like ours, includes both government consumption and investment, whereas most of the empirical literature either groups government consumption and investment together or focuses on government consumption. Zubairy (2014) estimates a medium scale DSGE model similar to ours and estimates a government spending multiplier of about 1.1. Her model differs from ours in focusing on deep habits as in Ravn, Schmitt-Grohé and Uribe (2006). Our model follows Bouakez and Rebei (2007) in instead allowing for complementarity between private and government consumption. Though our estimation methods differ and our model is a bit more complicated than theirs, we find roughly the same degree of complementarity between private and public consumption that they do. Coenen et al. (2012) calculate fiscal multipliers in seven popular DSGE models, and conclude that the output multiplier can be far in excess of one. Cogan, Cwik, Taylor and Wieland (2010) and Drautzburg and Uhlig (2015) conclude, in contrast, that the multiplier is likely less than unity. Leeper, Traum and Walker (2011) use Bayesian prior predictive analysis not to produce a point estimate of the multiplier, but rather to provide plausible bounds on it in a generalized DSGE framework. Whereas most of these papers focus on unproductive government expenditure (what we call government consumption in our model), Leeper, Walker and Yang (2010) include productive government investment in a neoclassical growth model with distortionary taxes. As noted by Parker (2011), almost all of the work on fiscal multipliers in DSGE models is based on linear approximations, which necessarily cannot address state-dependence.

A related literature studies the output multiplier and its interaction with the stance of monetary policy. In particular, there is a growing consensus that the multiplier can be substantially larger than normal under a passive monetary policy regime, such as the recent zero lower bound period. Early contributions in this regard include Krugman (1998) and Eggertson and Woodford (2003). Woodford (2011) conducts analytical exercises in the context of a textbook New Keynesian model without capital to study the multiplier, both inside and outside of the zero lower bound. Christiano, Eichenbaum and Rebelo (2011) analyze the consequences of the zero lower bound for the government spending multiplier in a DSGE model and find that the multiplier can exceed two. Though their paper focuses mostly on the output effects of government spending shocks at the zero lower bound, they do argue that it is optimal from a welfare perspective to increase government spending at the zero lower bound. Nakata (2013) reaches a similar conclusion that it is optimal to increase government spending when the zero lower bound binds. Fernández-Villaverde, Gordon, Guerrón-Quintana and Rubio-Ramirez (2015) analyze the consequences of the inherit non-linearity induced by the presence of the zero lower bound and highlight potential pitfalls with linear approximations.

Our work expands upon and contributes to the voluminous literature on fiscal multipliers in the following ways. First, our simultaneous focus on the output and welfare effects of government spending shocks differs from the majority of the empirical and theoretical literature, which focuses almost exclusively on the output effects of fiscal shocks. Our focus on the welfare effects of government spending shocks allows us to address the normative question of whether countercyclical government spending is desirable. Second, whereas a burgeoning empirical literature seeks to investigate whether there are important state-dependent effects of changes in government spending, most of the theoretical and quantitative literatures do not address state-dependence. An exception is Michaillat (2014), who embeds a search and matching model into a textbook New Keynesian model without capital to generate a counteryclical government spending multiplier. While we do find that there is some state-dependence to the government consumption multiplier (and much less so for the government investment multiplier), it is not large in an absolute sense and it is not countercylical. These quantitative results are closest to Ramey and Zubairy (2014) but differ sharply from Auerbach and Gorodnichenko (2012). Future research might expand upon our analysis to bridge the empirical and theoretical/quantitative work on state-dependent multipliers. Third, whereas most of the literature either focuses on shocks to government consumption or groups government investment and consumption together, our model explicitly allows for both types of government expenditure. Combined with our focus on the welfare effects of fiscal shocks, this allows us to shed light on questions such as how government expenditure ought to be split between consumption and investment and whether or not the desirability of countercyclical government expenditure differs depending on whether that expenditure is consumption or investment.

3 A Medium Scale DSGE Model

For our quantitative analysis, we consider a medium scale DSGE model with a number of real and nominal frictions and several shocks. The core of the model is similar to the models in Christiano et al. (2005), Smets and Wouters (2007), or Justiniano, Primiceri and Tambalotti (2010, 2011), among others. To this core, we add two kinds of government expenditure (consumption, from which households receive a utility flow, and investment, which affects the aggregate production function) and several different tax instruments. Section 3.1 describes the main features of the model, and Section 3.2 describes our parameterization of the model. Further details on the model are available in Appendix A.

3.1 Model Description

The subsections below lay out the decision problems of the key actors in the economy, specify stochastic processes for exogenous variables, and give aggregate equilibrium conditions.

3.1.1 Goods and Labor Aggregators

There exist a continuum of households, indexed by $h \in [0,1]$, and a continuum of firms, indexed by $j \in [0,1]$. Households supply differentiated labor and firms produce differentiated output. Differentiated labor inputs are combined into a homogeneous labor input via the technology:

$$N_t = \left(\int_0^1 N_t(h)^{\frac{\epsilon_w - 1}{\epsilon_w}} dh \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \quad \epsilon_w > 1 \tag{1}$$

$N_t(h)$ is labor supplied by household h and N_t is aggregate labor input. The parameter $\epsilon_w > 1$ is the elasticity of substitution among different varieties of labor. Profit-maximization gives rise to the following demand curve for each variety of labor:

$$N_t(h) = \left(\frac{w_t(h)}{w_t} \right)^{-\epsilon_w} N_t \tag{2}$$

Here $w_t(h)$ is the real wage charged by household h and w_t is the aggregate real wage, which can be written:

$$w_t^{1-\epsilon_w} = \int_0^1 w_t(h)^{1-\epsilon_w} dh \tag{3}$$

Each firm uses capital services and labor to produce differentiated output, $Y_t(j)$. This differentiated output is transformed into aggregate output, Y_t, via the technology:

(4) $$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}, \quad \epsilon_p > 1$$

In a way analogous to the labor market, profit maximization gives rise to the following downward-sloping demand curve for each variety of differentiated output and an aggregate price index:

(5) $$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_p} Y_t$$

(6) $$P_t^{1-\epsilon_p} = \int_0^1 P_t(j)^{1-\epsilon_p} dj$$

In (5)-(6), $P_t(j)$ is the price charged for the output variety j and P_t is the aggregate price index.

3.1.2 Households

Each household has identical preferences over private consumption, government consumption, and labor. Our preference specification permits non-separability between private and government consumption, but assumes that disutility from labor is additively separable from the other two arguments. This assumption on the separability of labor is common and facilitates the introduction of Calvo (1983) style staggered wage-setting. When combined with perfect insurance across households, as in Erceg, Henderson and Levin (2000), it implies that households will be identical along all margins except for labor supply and wages.[3] As such, when writing out the household's problem, we will omit dependence on h with the exception of labor market variables.

Our specification for flow utility is given by:

(7) $$U(C_t, G_t, N_t(h)) = \frac{\nu}{\nu - 1} \ln \widehat{C}_t - \xi_t \frac{N_t(h)^{1+\chi}}{1 + \chi}$$

$\widehat{C}_t$ is a composite of private and government consumption, C_t and G_t, respectively:

(8) $$\widehat{C}_t = \phi_G \left(C_t - bC_{t-1} \right)^{\frac{\nu-1}{\nu}} + (1 - \phi_G) G_t^{\frac{\nu-1}{\nu}}$$

The preference specification embodied in (7)-(8) is similar to that in Bouakez and Rebei (2007). The parameter $\phi_G \in [0, 1]$ measures the relative weights on private and government consumption, and $\nu > 0$ is a measure of the elasticity of substitution between the two. When $\nu < 1$, private and

[3] In earlier versions of this paper, we experimented with instead using the preference specification proposed by Schmitt-Grohé and Uribe (2006), which permits non-separability between consumption and labor with staggered wage-setting. This alternative specification does not have much effect on the results which follow.

government consumption are utility complements, and when $\nu > 1$ they are substitutes. When $\nu \to 1$, utility becomes additively separable in private and government consumption. The assumption of additive separability between private and government consumption is common in much of the literature. If preferences are separable, while the path of G_t is relevant for the dynamic equilibrium behavior of the model, the manner in which it enters utility is not. The parameter $b \in [0, 1)$ measures internal habit formation over private consumption. ξ_t is an exogenous stochastic variable governing the disutility from labor. The parameter $\chi > 0$ has the interpretation as the inverse Frisch labor supply elasticity.

The household discounts future utility flows by $\beta \in (0, 1)$. The exogenous variable v_t is a shock to the discount factor. Each period, the household faces a probability $1 - \theta_w$, with $\theta_w \in [0, 1)$, that it can adjust its nominal wage. Non-updated wages may be indexed to lagged inflation at $\zeta_w \in [0, 1]$. Households enter a period with a stock of government bonds, B_t, and a stock of physical capital, K_t. Households can save by accumulating more bonds or more capital. Nominal bonds are one period and pay out nominal interest rate $1 + i_t$ in the following period. The household can also choose how intensively to utilize its existing stock of physical capital. We denote utilization by u_t. The cost of more intensive utilization is faster depreciation. Capital services, $u_t K_t$, are leased to firms at rental rate R_t.

Formally, the household's problem can be expressed:

$$\max_{\substack{C_t, I_t, u_t, K_{t+1}, \\ B_{t+1}, w_t(h), N_t(h)}} \sum_{t=0}^{\infty} \beta^t v_t \left\{ \frac{\nu}{\nu - 1} \ln \widehat{C}_t - \xi_t \frac{N_t(h)^{1+\chi}}{1 + \chi} \right\} \tag{9}$$

s.t.

$$(1 + \tau_t^C) C_t + I_t + \frac{B_{t+1}}{P_t} \leq (1 - \tau_t^K) R_t u_t K_t + (1 - \tau_t^N) w_t(h) N_t(h) + \Pi_t - T_t + (1 + i_{t-1}) \frac{B_t}{P_t} \tag{10}$$

$$K_{t+1} = Z_t \left[1 - \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t + (1 - \delta(u_t)) K_t \tag{11}$$

$$\delta(u_t) = \delta_0 + \delta_1 (u_t - 1) + \frac{\delta_2}{2} (u_t - 1)^2 \tag{12}$$

$$N_t(h) \geq \left(\frac{w_t(h)}{w_t} \right)^{-\epsilon_w} N_t \tag{13}$$

$$w_t(h) = \begin{cases} w_t^{\#} & \text{if } w_t(h) \text{ chosen optimally} \\ (1 + \pi_{t-1})^{\zeta_w} (1 + \pi_t)^{-1} w_{t-1}(h) & \text{otherwise} \end{cases} \tag{14}$$

The flow budget constraint faced by a household is (10). τ_t^C, τ_t^K, and τ_t^N are proportional tax rates on consumption, capital income, and labor income. T_t is a lump sum tax. Π_t is lump sum profit resulting from the households' ownership of firms. Investment in new physical capital is denoted by I_t. Capital accumulates according to (11). $\kappa \geq 0$ is an investment adjustment cost as in Christiano et al. (2005). Z_t is an exogenous stochastic variable representing the marginal efficiency of investment, as in Justiniano et al. (2010, 2011). $\delta(u_t)$ is the depreciation rate on physical capital as a function of utilization. This cost is quadratic and is given in (12). The steady state level of utilization is normalized to unity, so $\delta_0 > 0$ governs steady state depreciation. $\delta_1 > 0$ is a parameter governing the linear term, and is chosen to be consistent with the steady state normalization. $\delta_2 > 0$ is the coefficient on the squared term and is what is relevant for short run dynamics. Constraint (13) requires that household labor supply meet demand. (14) describes wage-setting. With probability $1-\theta_w$, a household will update its real wage to $w_t^{\#}$. It is straightforward to show that all updating households will choose the same reset wage. Non-updated nominal wages are indexed to lagged inflation, π_{t-1}, at ζ_w. The first order optimality conditions for the households' problem are presented in Appendix A.1.

3.1.3 Firms

A typical firm, indexed by $j \in [0,1]$, produces differentiated output, $Y_t(j)$, according to the following production function:

$$Y_t(j) = \max\left\{A_t K_{G,t}^{\varphi} \widehat{K}_t(j)^{\alpha} N_t(j)^{1-\alpha} - F, 0\right\}, \quad 0 < \alpha < 1, \quad \varphi \geq 0, \quad F \geq 0 \tag{15}$$

Capital services, the product of physical capital and utilization, is denoted by $\widehat{K}_t$. A_t is an exogenous stochastic variable governing the level of aggregate productivity. It is common to all firms. As in Baxter and King (1993), our model allows for productive government capital, $K_{G,t}$. The accumulation equation for government capital is described below in Section 3.1.4. $\varphi \geq 0$ is a parameter governing the productivity of government capital. $F \geq 0$ is a fixed cost of production. It is required that production be non-negative.

From (5), firms have market power. As such, they are able to set their prices. Each period, we assume that a firm faces a constant probability, $1-\theta_p$, where $\theta_p \in [0,1)$, of being able to adjust its price. Non-updated prices may be indexed to lagged inflation at $\zeta_p \in [0,1]$. Regardless of whether a firm can adjust its price or not, it can choose inputs to minimize total cost subject to producing enough to meet demand at its price. The cost-minimization problem is:

$$\min_{\widehat{K}_t(j), N_t(j)} \quad w_t N_t(j) + R_t \widehat{K}_t(j) \tag{16}$$

s.t.

$$Y_t(j) \geq \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_p} Y_t \tag{17}$$

Because firms face the same aggregate level of productivity, the same level of government capital, and the same factor prices, cost-minimization implies that they all have the same marginal cost and will hire capital services and labor in the same ratio. A firm given the opportunity to adjust its price will do so to maximize the presented discounted value of its flow profit, where discounting is by the stochastic discount factor of the household (which, given separability between consumption is labor, is the same across households). A firm's price will therefore satisfy:

$$P_t(j) = \begin{cases} P_t^{\#} & \text{if } P_t(j) \text{ chosen optimally} \\ (1+\pi_{t-1})^{\zeta_p} P_{t-1}(j) & \text{otherwise} \end{cases} \tag{18}$$

Because firms all have the same marginal cost, it is straightforward to show that all updating firms will choose the same reset price, $P_t^{\#}$. The full set of optimality conditions for firms is presented in Appendix A.2.

3.1.4 Government

A government sets monetary and fiscal policy. The flow government constraint for the fiscal authority is given by:

$$G_t + G_{I,t} + i_{t-1}\frac{B_{G,t}}{P_t} \leq \tau_t^C C_t + \tau_t^N \int_0^1 w_t(h) N_t(h) dh + \tau_t^K R_t \widehat{K}_t + T_t + \frac{B_{G,t+1}}{P_t} - \frac{B_{G,t}}{P_t} \tag{19}$$

In (19), $G_{I,t}$ denotes government investment in new physical capital and $B_{G,t}$ denotes the stock of debt with which the government enters a period. The expenditure side of the budget constraint consists of government consumption, G_t, government investment, $G_{I,t}$, and interest payments on the real value of outstanding government debt brought into the period. Expenditure can be financed either with tax revenue, which consists of revenue from consumption, labor, and capital taxation as well as lump sum taxes, or by issuing new debt.

The government enters a period with an inherited stock of capital, $K_{G,t}$. This capital depreciates at $\delta_G \in (0,1)$. Government capital accumulates according to the following law of motion:

$$K_{G,t+1} = G_{I,t} + (1-\delta_G) K_{G,t} \tag{20}$$

We assume that government consumption and investment obey independent stationary AR(1) processes:[4]

[4] In the data, the log first differences of government consumption and investment are mildly positively correlated. Our specification abstracts from this feature of the data. Including it in our model does not affect any substantive

$$\ln G_t = (1-\rho_G)\ln G + \rho_G \ln G_{t-1} + s_G \varepsilon_{G,t} \tag{21}$$

$$\ln G_{I,t} = (1-\rho_{G_I})\ln G_I + \rho_{G_I} \ln G_{I,t-1} + s_{G_I} \varepsilon_{G_I,t} \tag{22}$$

In (21)-(22) and for the remainder of the paper, variables without a time subscript denote non-stochastic steady state values (e.g. G is the non-stochastic steady state value of government consumption). The autoregressive parameters are both restricted to lie between 0 and 1. $\varepsilon_{G,t}$ and $\varepsilon_{G_I,t}$ are independent shocks drawn from standard normal distributions. The standard deviations of the shocks are s_G and s_{G_I}.

The tax instruments obey the following processes:

$$\tau_t^C = (1-\rho_C)\tau^C + \rho_C \tau_{t-1}^C + (1-\rho_C)\gamma_C\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{23}$$

$$\tau_t^N = (1-\rho_N)\tau^N + \rho_N \tau_{t-1}^N + (1-\rho_N)\gamma_N\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{24}$$

$$\tau_t^K = (1-\rho_K)\tau^K + \rho_K \tau_{t-1}^K + (1-\rho_K)\gamma_K\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{25}$$

$$T_t = (1-\rho_T)T + \rho_T T_{t-1} + (1-\rho_T)\gamma_T\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{26}$$

Each tax instrument is assumed to obey a stationary AR(1) process (so the autoregressive parameters are constrained to lie between 0 and 1). Taxes react to deviations of the debt-gdp ratio from an exogenous steady state target, $\frac{B_G}{Y}$. These reactions are governed by the γ_f parameters, for $f = C, N, K, T$. We restrict attention to values of these parameters consistent with a non-explosive path of the debt-gdp ratio.

Monetary policy is conducted according to a fairly conventional Taylor rule:

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\left[\phi_\pi \pi_t + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_i \varepsilon_{i,t} \tag{27}$$

In the Taylor rule, $\rho_i \in [0,1)$ is a parameter governing interest smoothing, ϕ_π is a parameter governing the reaction of the nominal interest rate to inflation, and ϕ_y dictates the response to output growth. In our quantitative exercises, we focus on a zero inflation, zero trend growth

results.

equilibrium. $\varepsilon_{i,t}$ is a shock drawn from a standard normal distribution, and s_i is the standard deviation of the shock.

3.1.5 Exogenous Processes

In addition to government consumption and investment, the model contains four other exogenous variables – A_t (a measure of aggregate productivity), Z_t (a measure of the marginal efficiency of investment), v_t (a shock to the discount factor), and ξ_t (a shock to the disutility from labor). These each follow stationary AR(1) processes in the log:

$$\ln A_t = (1 - \rho_A) \ln A + \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \tag{28}$$

$$\ln Z_t = \rho_Z \ln Z_{t-1} + s_Z \varepsilon_{Z,t} \tag{29}$$

$$\ln v_t = \rho_v \ln v_{t-1} + s_v \varepsilon_{v,t} \tag{30}$$

$$\ln \xi_t = (1 - \rho_\xi) \ln \xi + \rho_\xi \ln \xi_{t-1} + s_\xi \varepsilon_{\xi,t} \tag{31}$$

All autoregressive parameters are restricted to lie between 0 and 1. The non-stochastic steady state values of Z and v are normalized to 1. The non-stochastic steady state values of productivity and the labor supply shifter are given by A and ξ.

3.1.6 Aggregation and Equilibrium

The definition of an equilibrium is standard. All budget constrains hold with equality, households hold all government debt, and markets for capital services and labor clear. The aggregate resource constraint is:

$$Y_t = C_t + I_t + G_t + G_{I,t} \tag{32}$$

The aggregate production function is:

$$v_t^p Y_t = A_t K_{G,t}^{\varphi} \widehat{K}_t^{\alpha} N_t^{1-\alpha} - F \tag{33}$$

v_t^p is a measure of price dispersion. It can be written:

$$(34) \qquad v_t^p = (1+\pi_t)^{\epsilon_p}\left[(1-\theta_p)(1+\pi_t^{\#})^{-\epsilon_p} + \theta_p(1+\pi_{t-1})^{-\zeta_p\epsilon_p} v_{t-1}^p\right]$$

Combining properties of Calvo (1983) price- and wage-setting with (6) and (3), inflation and the aggregate real wage index are:

$$(35) \qquad (1+\pi_t)^{1-\epsilon_p} = (1-\theta_p)(1+\pi_t^{\#})^{1-\epsilon_p} + \theta_p(1+\pi_{t-1})^{\zeta_p(1-\epsilon_p)}$$

$$(36) \qquad w_t^{1-\epsilon_w} = (1-\theta_w) w_t^{\#,1-\epsilon_w} + \theta_w \left(\frac{(1+\pi_{t-1})^{\zeta_w}}{1+\pi_t} w_{t-1}\right)^{1-\epsilon_w}$$

We define real government debt as $b_{g,t} = \frac{B_{G,t}}{P_{t-1}}$. Given properties of the aggregate real wage index, the government's flow budget constraint can be written without reference to household subscripts as:

$$(37) \qquad G_t + G_{I,t} + i_{t-1}(1+\pi_t)^{-1} b_{g,t} \leq \tau_t^C C_t + \tau_t^N w_t N_t + \tau_t^K R_t \widehat{K}_t + T_t + b_{g,t+1} - b_{g,t}(1+\pi_t)^{-1}$$

Appendix A lists the full set of equilibrium conditions for the model.

3.2 Parameterization and Estimation

Our approach is to first calibrate several parameters that are closely tied to long run moments of the data or are difficult to estimate. The remaining parameters are estimated via Bayesian methods.

As a benchmark, we assume that all distortionary taxes are constant at zero. This implies that the exact mix between lump sum tax and bond finance is irrelevant for the behavior of the economy. We can thus ignore parameters governing the tax processes altogether, and need not specify the steady state level of government debt. While this is undoubtedly unrealistic, it is fairly common to omit distortionary taxation in the estimation and analysis of medium scale models. We consider robustness to alternative means of fiscal finance in Section 5.1.

Parameters which are calibrated include $\{\beta, \alpha, \delta_0, \delta_1, \delta_G, \epsilon_p, \epsilon_w, F, G, G_I, A, \xi, \phi_G, \nu\}$. These are listed in Table 1. The unit of time is taken to be a quarter. Accordingly, the discount factor is set to $\beta = 0.995$, implying an annualized risk free real interest rate of two percent. The parameter $\alpha = 1/3$. The linear term in the utilization cost function is set to $\delta_0 = 0.025$, implying a steady state annualized depreciation rate of ten percent. The depreciation rate on government capital is also set at $\delta_G = 0.025$. The linear term in the utilization cost function, δ_1, is chosen to be consistent with the normalization of steady state utilization to one. The fixed cost of production, F, is chosen to be consistent with zero steady state profit. The steady state disutility of labor, ξ, is chosen to be consistent with steady state labor hours of 1/3. The elasticities of substitution for both goods and labor are set to $\epsilon_p = \epsilon_w = 11$, which implies ten percent steady state price and wage markups. The steady state values of government consumption and investment are set as follows. For the period 1984-2008, we calculate the nominal ratios of government consumption expenditures to total GDP and gross government investment to total GDP. The steady state values of G and G_I are set to be consistent with the average values of these ratios over this period. Steady state government capital is $K_G = \frac{G_I}{\delta_G}$. Given a value of φ (discussed below), we choose the steady state value of A to be consistent with $AK_G^{\varphi} = 1$, which normalizes steady state measured TFP to unity.

Two important parameters for our analysis which are calibrated, rather than estimated, are ϕ_G and φ. ϕ_G is the weight on private consumption in the utility function. We choose a value of $\phi_G = 0.8$. This is the same value assumed by Bouakez and Rebei (2007). As we discuss further in Appendix C, ϕ_G and ν are separately poorly identified, at least locally. We set the parameter φ, which governs the productivity of government capital, to 0.05. This is the benchmark value assumed in Baxter and King (1993) and Leeper, Walker and Yang (2010), the latter of whom also calibrate, rather than estimate, this parameter. Leduc and Wilson (2013) assume a value of the equivalent to our parameter φ of 0.10. There seems to be no strong consensus in the empirical literature on the productivity of government capital. Early work based on estimating log-linear production functions tends to find relatively large values of the equivalent of our parameter φ (see, e.g. Aschauer 1989 or Munnell 1992). This literature is criticized by Holtz-Eakin (1994), who finds no relationship between government capital and private productivity. Evans and Karras (1994) reach a similar conclusion. We consider robustness to different values of ϕ_G and φ in Section 4.4.

The remaining parameters are estimated. The observable variables in our estimation include the log first differences of output, consumption, hours worked, government consumption, and government investment, and the levels of the inflation rate and the nominal interest rate. Nominal output is measured as the headline NIPA number. Nominal consumption is measured as the sum of non-durable and services consumption. Nominal government consumption and investment are total government consumption expenditures and gross government investment from the NIPA tables. Hours worked is total hours worked in the non-farm business sector divided by the civilian non-institutionalized population aged sixteen and over. The interest rate is measured as the three month Treasury Bill rate. Nominal series are converted to real by deflating by the GDP implicit price deflator. Inflation is the log first difference of the price deflator. The sample period is 1984q1-2008q3. The beginning date is chosen because of the sharp break in volatility in the early 1980s and the end date is chosen so as to exclude the zero lower bound.

The prior and posterior distributions for the estimated parameters are presented in Table 2. Overall the posterior distributions are quite reasonable and are generally in line with the existing literature. Of the estimated parameters, the only non-standard one is ν, which governs the elasticity of substitution between private and government consumption. The posterior mode of this parameter is 0.2850, which suggests that private and government consumption are strong utility complements. This estimate is very similar to Bouakez and Rebei (2007), who estimate this parameter by matching impulse responses of private consumption to a government spending shock identified from a VAR.

In the data, the unconditional correlation between private and government consumption is mildly positive (0.12 in our data). The parameter ν being significantly less than one allows the model to match this moment. Fixing $\nu = 1$, which results in flow utility being additively separable in private and government consumption, has little effect on the estimates of other parameters, but results in the model generating an unconditional correlation between consumption and government spending which is negative.

When solved using the mode of the posterior distribution, the model generates other second moments which are close to their empirical counterparts. In terms of accounting for business cycle dynamics, the shock to the marginal efficiency of investment is the most important shock, accounting for about 50 percent of the unconditional variance of output growth. This is in line with the findings in Justiniano et al. (2010, 2011). The productivity shock is much less important, accounting for about 10 percent of the unconditional variance of output. The labor supply shock explains roughly 25 percent of the variance of output growth. The intertemporal preference shock, monetary policy shock, and the two types of government spending shocks account for the remaining unconditional variance of output growth, but each individually is relatively unimportant in accounting for output dynamics in the model.

4 Baseline Results

This section presents our baseline simulation results from the estimated model. Section 4.1 describes our quantitative exercises, and our baseline results are presented and discussed in Section 4.2. Section 4.3 provides some intuition for our quantitative results. In Section 4.4, we consider the robustness of our results to different values of the calibrated parameters governing the usefulness of government expenditure. Section 4.5 considers robustness of our results to other model parameters.

4.1 Multiplier Definitions and Quantitative Simulations

We solve the model laid out in Section 3 using a third order approximation about the non-stochastic steady state. The model is solved using the posterior mode of the estimated parameters. We define two fiscal output multipliers – one for government consumption, $\frac{dY_t}{dG_t}$, and one for government investment, $\frac{dY_t}{dG_{I,t}}$. In practice, these multipliers are computed by constructing impulse responses to shocks to government consumption or government investment, respectively, and taking the ratio of the impact response of output to the impact response of government consumption or investment. For most specifications of the model, the output response is largest to either kind of government spending shock on impact.

In a higher order approximation, impulse response functions to shocks will depend on the initial state vector, $\mathbf{s}_{t-1}$. Formally, we define the impulse response function of the vector of endogenous variables, $\mathbf{x}_t$, to shock m as:

$$\mathrm{IRF}_m(h) = \left\{ \mathbf{E}_t \mathbf{x}_{t+h} - \mathbf{E}_{t-1} \mathbf{x}_{t+h} \mid \mathbf{s}_{t-1}, \varepsilon_{m,t} = s_m \right\}, \quad h \geq 0 \tag{38}$$

In words, the impulse response function to shock m measures the change in the conditional forecast of the vector of variables conditional on both (i) the initial value of the state vector, $\mathbf{s}_{t-1}$, and (ii) the realization of a one standard innovation shock, s_m, to shock m. The impulse response function will in general depend on both the magnitude and sign of the innovation. In what follows, we focus on one standard deviation innovations. In practice, these impulse response functions are computed via simulation. Given the initial value of the state, we compute two simulations of the endogenous variables out to a forecast horizon of H using the same draw of stochastic shocks. In one of these simulations we add s_m to the realization of shock m in the first period. This process is repeated T times. We then average (across T) over the realized values of endogenous variables up to forecast horizon H. The difference at each forecast horizon between the averaged simulations with and and without the extra one standard deviation shock in the first period is the impulse response function. We use $H = 10$ and $T = 50$.

We also wish to investigate how shocks to government consumption or investment impact a measure of aggregate welfare. We define aggregate welfare, $\mathbb{W}_t$, as the equally weighted sum of the present discounted value of flow utility across households. As we show in Appendix B, aggregate welfare can be written recursively in terms of aggregate variables only as:

$$\mathbb{W}_t = v_t \frac{\nu}{\nu - 1} \ln \widehat{C}_t - v_t \xi_t v_t^w \frac{N_t^{1+\chi}}{1+\chi} + \beta E_t \mathbb{W}_{t+1} \tag{39}$$

In (39), v_t^w is a measure of wage dispersion which can be written recursively as:

$$v_t^w = (1 - \theta_w) \left(\frac{w_t^{\#}}{w_t} \right)^{-\epsilon_w (1+\chi)} + \theta_w \left(\frac{w_t}{w_{t-1}} \frac{1 + \pi_t}{(1 + \pi_{t-1})^{\zeta_w}} \right)^{\epsilon_w (1+\chi)} v_{t-1}^w \tag{40}$$

When solving the model, we simply include the expressions (39) and (40) as equilibrium conditions. We define the welfare multipliers for each type of government spending shock as $\frac{d\mathbb{W}_t}{dG_t}$ and $\frac{d\mathbb{W}_t}{dG_{I,t}}$ for government consumption and investment, respectively. In words, these multipliers convey how much aggregate welfare changes for a one unit change in government consumption or investment. The units of welfare are utils, and the magnitudes of the welfare multipliers are therefore difficult to interpret. As such, we also compute consumption equivalent measures. In particular, we numerically solve for the amount of consumption a household must be given (or have taken away) for one period to generate an equivalent change in welfare of $\frac{d\mathbb{W}_t}{dG_t}$ or $\frac{d\mathbb{W}_t}{dG_{I,t}}$.

We compute output and welfare multipliers for each type of government spending shock conditional on different realizations of the state vector, $\mathbf{s}_{t-1}$. We first compute multipliers where the initial state is the non-stochastic steady state of the model. We compute other states from which to compute multipliers by drawing from the ergodic distribution of states. In particular, we simulate 10,100 periods from the model starting from the non-stochastic steady state. The first 100 periods are dropped as a burn-in. For each remaining 10,000 simulated values of the state vector, we compute output and welfare multipliers to both kinds of government spending shocks. We then analyze summary statistics for the resulting distributions of output and welfare multipliers.

4.2 Results

Table 3 presents output and welfare multipliers for each type of government spending shock when the initial state is the non-stochastic steady state. The steady state output multiplier for government consumption is 1.07. In response to an increase in government consumption, private consumption increases while investment declines. The increase in private consumption is driven by the estimated complementarity between government and private consumption, and is the reason why the multiplier is greater than one. The estimated steady state welfare multiplier is -2.41. Converted to consumption equivalent terms, this is equivalent to a one period reduction in consumption of -0.17, which is about one-third of steady state consumption. This means that, evaluated in the steady state, an increase in government spending lowers aggregate welfare, in spite of the fact that consumption increases and the output multiplier exceeds one.

The estimated output multiplier for government investment evaluated in the steady state is 0.90. The welfare multiplier is positive at 3.18, or 0.33 in consumption equivalent terms. This means that aggregate welfare increases after a positive shock to government investment, in spite of the fact that the output multiplier is less than one.

That the steady state welfare multiplier for government consumption is negative but is positive for government investment is suggestive that the amount of government consumption is higher in steady state, and government investment lower, than households would prefer. To investigate the optimal size of steady state government spending, we solve for the optimal steady state output shares of government consumption and investment. The optimal steady state shares in our estimated model are $\frac{G}{Y}$ = 0.148 and $\frac{G_I}{Y}$ = 0.057, compared to the average values from the data used in our calibration of 0.152 and 0.043, respectively. The total government spending share of output would be 0.205 to optimize steady state welfare, compared to 0.195 as observed in the data. Given our parameterizations of ϕ_G and φ (to which we return more below), our analysis suggests that the overall size of government spending is close to optimal, but that spending should be shifted from consumption into investment.

Table 4 presents statistics from the distribution of multipliers. These are generated by computing multipliers conditional on 10,000 different realizations of the state vector. The average output multiplier for government consumption is 1.06, very close to the steady state multiplier. The output multiplier is not constant across states. The standard deviation of the output multiplier is 0.017, with a minimum value of 1 and a maximum value of 1.13. The output multiplier for government consumption is positively correlated with the simulated value of output at 0.27. This means that the output multiplier is actually slightly lower than average when output is low.

The mean welfare multiplier for government consumption is -2.33. This multiplier is quite variable across states. In consumption equivalent terms, the mean value is -0.14, the standard deviation across states is 0.09, and the minimum and maximum values are -0.29 and 0.34, respectively. The welfare multiplier is positively correlated with the simulated level of output, with a correlation of 0.50 with simulated output, or 0.45 when focusing on the correlation between the consumption equivalent welfare multiplier and output. The positive correlation between the welfare multiplier and simulated output means that increases in government consumption are most attractive in periods in which output is relatively high. In our simulations, the welfare multiplier is positive in 7 percent of simulated states. On average, output is 3.5 percent above its mean in these periods.

The mean government investment multiplier is 0.90. This is much less variable across states than is the consumption multiplier, with a min-max range of only 0.88-0.92. The investment multiplier is negatively correlated with simulated output. The mean welfare multiplier for government investment is 3.13, or 0.32 in consumption equivalent terms. The welfare multiplier is substantially more volatile than the output multiplier. The welfare multiplier is essentially uncorrelated with simulated output, and the consumption equivalent welfare multiplier is only mildly negative correlated with output. In our simulations, the welfare multiplier for government investment is never negative.

Figure 1 plots the impulse responses of output to government consumption (left column) or investment shock (right column) conditional on three different initial states. Solid lines correspond to the non-stochastic steady state, dashed lines the state generating the smallest output multiplier, and dotted lines the state generating the largest output multiplier. The impulse response of output at each horizon is scaled by the inverse of the impact response of government expenditure so to express the response in "multiplier form." For government consumption shocks, there are significant differences in the output response across states, and these differences persist over many forecast horizons. The differences in the output response across states to a government investment shock are much less noticeable. Figure 2 plots histograms of the output (left panel) and welfare (right panel) multipliers for both government consumption shocks (upper row) and government investment shocks (lower row). The distributions of multipliers are roughly symmetric about their means for both kinds of government expenditure shocks. For both the output and welfare multipliers, the distributions for government consumption are substantially more disperse than for government investment.

To get a sense of what the multipliers look like in periods of depressed output, we define recessions as periods in which simulated output is in its lowest 20th percentile. At the bottom of Table 4, we show average multipliers conditional on periods identified as recessions. For government consumption, the average output multiplier conditional on a recession is slightly lower than its unconditional mean, while the reverse is true for government investment. For government consumption, the average welfare multiplier conditional on being in a recession is lower than its unconditional mean. For government investment, there is little difference between the average welfare multiplier conditional on a recession and its unconditional mean.

We next investigate what the multipliers look like in recessions caused by particular kinds of shocks. To do so, we proceed as follows. For each of five different kinds of shocks – productivity, investment, intertemporal preference, labor supply, and monetary policy – we solve for the magnitude of the shock which would result in output on average falling to its lowest 20th percentile six quarters subsequent to the shock, starting from the non-stochastic steady state. We then conduct 10,000 simulations, starting from the non-stochastic steady state but adding in this magnitude of shock in the first period of the simulation. We then compute the output and welfare multipliers six quarters subsequent to the shock in each of the 10,000 different simulations.

Table 5 shows the mean multipliers for both government consumption and investment from these experiments. One can think of these numbers as reflecting the average multipliers in a typical recession generated by a particular shock. For government consumption, the output multiplier is slightly lower than average conditional on recessions caused by productivity and intertemporal preference shocks, and slightly higher than average conditional on investment and monetary policy shocks. The welfare multiplier is lower than average in typical recessions caused by all but the intertemporal preference shock. The average output multiplier for government investment is roughly the same in typical recessions generated by all but the monetary policy shock, where the output multiplier is slightly higher than average. The welfare multiplier is higher than average in a typical recession caused by investment, intertemporal preference, or labor supply shocks, and is lower than average in recessions due to productivity or monetary policy shocks.

It is interesting to note that, for both government consumption and investment, the elasticities of output with respect to government spending – i.e. $\frac{d \ln Y_t}{d \ln G_t}$ and $\frac{d \ln Y_t}{d \ln G_{I,t}}$ – are substantially more volatile across states than are the multipliers. Ramey and Zubairy (2014) note that empirical work on state-dependent fiscal multipliers often follows the practice of first estimating state-dependent output elasticities with respect to government spending, and then converts these elasticities to multiplier form by post-multiplying by the average ratio of output to government spending. This is the practice in, for example, Auerbach and Gorodnichenko (2012). Ramey and Zubairy (2014) argue that this practice is likely to overstate the variability in multipliers across states, and is also biased towards finding that the multipliers co-vary negatively with output. This is because government expenditure (either government investment or consumption) is not very cyclical, meaning that the output to government expenditure ratio is procyclical. This means that multiplication by a fixed output to government spending ratio tends to bias a multiplier constructed in this fashion to be high in periods in which output is low.

Our analysis confirms that this criticism of Ramey and Zubairy (2014) might be quantitatively important. When re-doing the analysis described in Table 4, but constructing multipliers based on elasticities using the average output to government spending ratios, we find the following. Both the government consumption and investment multipliers appear substantially more volatile – for government consumption, the standard deviation of the output multiplier across states is 0.036 (compared to the true standard deviation of 0.017) and the volatility of the government investment multiplier is 0.052 (compared to 0.0042). The incorrect conversion of elasticities into multipliers also impacts the co-movement of the multipliers with simulated output. For government consumption, the correlation of the incorrectly constructed output multiplier with simulated output is -0.86 (as opposed to 0.27), and for government investment the correlation of the incorrect output multiplier with simulated output is -0.58 (as opposed to -0.29).

4.3 Intuition

Our quantitative analysis suggests that the average government consumption multiplier is greater than one, while the average government investment multiplier is less than one. The average welfare multiplier for government consumption is negative and strongly positively correlated with output, while the welfare multiplier for government investment is positive on average and uncorrelated with simulated output. The normative implications of these results are that government expenditure ought to shift from consumption to investment in an average sense, and there is little justification for countercyclical government expenditure (especially for government consumption).

In this section, we seek to develop some intuition for these results. To do so, we consider a highly simplified version of the economy specified in Section 3. The simplified model abstracts from private capital accumulation, habit formation in consumption, a fixed cost in production, wage stickiness, and price dispersion. We also do not formally model the firms' optimization problem, taking the price markup as a measure for overall distortion in the economy. Our simplified economy is summarized by the following conditions:

$$Y_t = C_t + G_t + G_{I,t} \tag{41}$$

$$Y_t = A_t K_{G,t}^{\varphi} N_t \tag{42}$$

$$w_t = \mu_t^{-1} A_t K_{G,t}^{\varphi} \tag{43}$$

$$U_t = u(C_t, G_t) - l(N_t) \tag{44}$$

$$l_N(N_t) = u_C(C_t, G_t) w_t \tag{45}$$

$$K_{G,t+1} = G_{I,t} + (1 - \delta_G) K_{G,t} \tag{46}$$

The modified resource constraint is given by (41) and (42) is the modified production function. Labor demand is given by (43). Here, μ_t is the markup of price over marginal cost; in an efficient allocation, it would be fixed at one and the wage would equal the marginal product of labor. Flow utility is given by (44). Consistent with the utility specification in the medium scale model, we assume that $u_C > 0$, $u_{CC} < 0$, $u_{CG} \geq 0$, $l_N > 0$, and $l_{NN} > 0$. The static first order condition for labor supply is (45). The law of motion for government capital is (46).

Totally differentiating these expressions about a point (denoted by the lack of a time subscript) and simplifying yields expressions for the government consumption and investment multipliers:

$$\frac{dY_t}{dG_t} = \underbrace{\frac{-u_{CC} + u_{CG}}{l_{NN}\frac{\mu}{(AK_G^{\varphi})^2} - u_{CC}}}_{\text{Efficiency}} - \underbrace{\frac{u_C}{l_{NN}\frac{\mu}{(AK_G^{\varphi})^2} - u_{CC}}\frac{d\mu_t/\mu}{dG_t}}_{\text{Inefficiency}} \tag{47}$$

$$\frac{dY_t}{dG_{I,t}} = \underbrace{\frac{-u_{CC}}{l_{NN}\frac{\mu}{(AK_G^{\varphi})^2} - u_{CC}}}_{\text{Efficiency}} - \underbrace{\frac{u_C}{l_{NN}\frac{\mu}{(AK_G^{\varphi})^2} - u_{CC}}\frac{d\mu_t/\mu}{dG_{I,t}}}_{\text{Inefficiency}} \tag{48}$$

The government consumption multiplier is (47) and the investment multiplier is (48); these only differ by the presence of the cross partial between output and government consumption in the numerator of the terms labeled "efficiency." These expressions are similar to those derived in Woodford (2011). We label the first terms in these expressions "efficiency" because these are what the multipliers would equal in an efficient allocation (since the markup would be fixed at one in an efficient allocation). Given assumptions on preferences, both efficiency terms are positive. The efficiency term for government investment must be less than one, whereas it could exceed one for the consumption multiplier if complementarity between private and government consumption is sufficiently strong. The second terms in each expression are identical, and we label them "inefficiency." These terms are labeled inefficiency because they depend on how the price markup reacts to a government spending change. The coefficient multiplying the reaction of the markup is positive. Since this term is subtracted from the efficiency term in each expression, if government expenditure increases result in falling markups, then the inefficiency terms will work to make both multipliers larger. The markup will typically fall after an increase in either type of government expenditure, and will fall more the stickier are prices and the less aggressive is monetary policy. Hence, both the government consumption and investment multipliers ought to be bigger the stickier are prices and/or the less aggressive is monetary policy.

It is not particularly straightforward to use (47)-(48) to think about intuition for how the output multipliers ought to vary across states, as this depends on third derivatives of the utility function and the reaction of the price markup to a spending shock. One thing to note, however, is that both multipliers ought to be smaller, other things being equal, the more distorted is the economy (i.e. the larger is μ). In our quantitative simulations, the price markup is countercylical. This is a potential explanation for why we find that the government consumption multiplier is positively correlated with output, and the government investment multiplier is only weakly negatively correlated with output.

We can derive an expression for the utility multiplier for each type of government expenditure by totally differentiating flow utility about a point and using the total derivatives of some of the other expressions. The welfare multiplier would simply be the presented discounted value of utility multipliers. The utility multipliers for each type of government expenditure are:

$$\frac{dU_t}{dG_t} = \underbrace{u_G - u_C}_{\text{Efficiency}} + \underbrace{\frac{l_N}{AK_G^{\varphi}}(\mu - 1)\frac{dY_t}{dG_t}}_{\text{Inefficiency}} \tag{49}$$

$$\frac{dU_t}{dG_{I,t}} = \underbrace{-u_C}_{\text{Efficiency}} + \underbrace{\frac{l_N}{AK_G^{\varphi}}(\mu - 1)\frac{dY_t}{dG_{I,t}}}_{\text{Inefficiency}} \tag{50}$$

The utility multipliers for each type of government expenditure again look similar, with the only substantive difference being the absence of the u_G term in the expression for the government investment utility multiplier, (50). We again label the two terms in these expressions "efficiency" and "inefficiency." In an efficient allocation, $\mu = 1$, so the second terms would drop out. In the efficient case, the utility multipliers would only depend upon the difference in the marginal utilities of government expenditure and private consumption. For both types of government expenditure, we observe that the utility multipliers will be larger, holding other factors constant, the more distorted is the economy (i.e. the bigger is μ) and the larger is the output multiplier. The government consumption utility multiplier will be larger the more highly households value government consumption (i.e. the bigger is u_G).

The efficiency terms will tend to make the utility multipliers for both type of government expenditure negatively correlated with output. In periods of low output, consumption is low, and hence the marginal utility of consumption is high. This makes it undesirable to increase government expenditure in periods of low output. The inefficiency terms may work in the opposite direction. To the extent to which the economy is relatively distorted when output is low, the inefficiency term will be more positive in periods of low output. This potentially justifies countercylical government expenditure.

One might wonder how it can be that we find that the welfare multiplier for government consumption is positively correlated with output, since consumption increases after a government consumption shock and the marginal utility of consumption is high in periods where output is low. (49) can be re-arranged to yield:

$$\frac{dU_t}{dG_t} = u_C\frac{dC_t}{dG_t} + u_G - \frac{l_N}{AK_G^{\varphi}}\frac{dY_t}{dG_t} \tag{51}$$

In (51), the fist term captures the intuition that an increase in consumption, $\frac{dC_t}{dG_t} > 0$, is particularly valuable when output is low (because u_C is relatively high). But the main mechanism in the model driving a positive response of private consumption to government consumption is complementarity. This has the implication that the marginal utility of government consumption, u_G, is relatively low in periods where private consumption is low. This term works in the opposite direction, tending to make the utility multiplier low in periods where output is low. Our analysis therefore suggests that while complementarity between private and government consumption can result in an output multiplier greater than one and a positive response of consumption to a change in government spending, it is not likely a good motivation for countercyclical government consumption.

Since in our model $u_G > 0$ and $\frac{dY_t}{dG_t} > \frac{dY_t}{dG_{I,t}}$, one might examine (49)-(50) and wonder how we find that the average welfare multiplier for government investment is positive, while it is negative for government consumption. It is important to emphasize that the welfare multiplier can be thought of as the present discounted value of utility multipliers. In response to a government investment shock, government capital does not react within period, but will adjust in the future. This means that there are additional terms in *future* utility multipliers for government investment related to the adjustment of the stock of government capital. It is these terms that drive the positive average welfare multiplier for government investment.

4.4 Robustness to Key Parameters

Two key parameters related to government expenditure are calibrated in our analysis, rather than estimated. These are ϕ_G, which governs the utility weight on government consumption, and φ, which measures the productivity of government expenditure. In this section we examine the sensitivity of our results to these parameters.

We consider two alternative values of the utility weight parameters, $\phi_G = 0.7$ and $\phi_G = 0.9$, and two different values of the exponent on government capital in the production function, $\varphi = 0.02$ and $\varphi = 0.10$. For these different parameter values, we separately re-estimate the parameters of the model, using the same prior distributions and calibrated values of all but the relevant parameter (ϕ_G or φ). The posterior modes of the estimated parameters for different values of ϕ_G or φ are presented in Table 6. With only one exception, the posterior modes of the estimated parameters are virtually the same as in Table 2 regardless of assumed value of ϕ_G or φ. The one exception concerns the posterior mode of ν for different values of ϕ_G. When ϕ_G is lower, the posterior mode of ν is larger, and is smaller when ϕ_G is relatively high. This pattern is consistent with our discussion laid out in Appendix C. What is relevant for the dynamic behavior of the observed variables in our estimation is the elasticity of the marginal utility of wealth with respect to government consumption. This elasticity is affected both by ϕ_G and ν in a way consistent with what we find when re-estimating the model for different fixed values of ϕ_G. In particular, when ϕ_G is lower and ν is higher, the elasticity of wealth with respect to government consumption is roughly the same as in our baseline.

In Table 7, we present results from our benchmark quantitative exercises assuming different values of ϕ_G or φ. For these exercises, we set other parameters to the posterior mode (given in Table 6) conditional on the different assumed value of ϕ_G or φ. The exercise is otherwise identical to that described in Table 4. When $\phi_G = 0.7$ instead of $\phi_G = 0.8$, households place a higher weight on government consumption in the utility function. This has little effect on the properties of the output multiplier – its mean and standard deviation across states are virtually the same as when $\phi_G = 0.8$, and it is again mildly positively correlated with simulated output. The average welfare multiplier, in contrast, is now significantly positive, instead of negative. It is fairly intuitive that the average welfare multiplier is larger when households place a higher weight on government consumption. Relative to when $\phi_G = 0.8$, the welfare multiplier is not quite as volatile across states, but it remains strongly procyclical. When $\phi_G = 0.9$, the average output multiplier is about the same as under our benchmark assumption, though it is more volatile across states. It remains positively correlated with output. The welfare multiplier, in contrast, is even more negative on average than with $\phi_G = 0.8$. This is again intuitive, since a higher value of ϕ_G means that households place a lower utility weight on government consumption. The welfare multiplier is again strongly positively correlated with simulated output, slightly moreso than when $\phi_G = 0.8$ or 0.7. We conclude from these exercises that while ϕ_G has important effects on the sign and magnitude of the welfare multiplier, it plays a minor role in the properties of the output and welfare multipliers across states. In particular, the welfare multiplier is strongly positively correlated with output regardless of ϕ_G.

We next focus on different values of φ, which governs the productivity of government capital. ϕ_G is set to its benchmark value of 0.8. Results are summarized in the bottom panel of Table 7. When $\varphi = 0.02$ (instead of its benchmark assumed value of 0.05), the output multiplier is slightly smaller on average but remains roughly constant across states. The average welfare multiplier, in contrast, is quite negative (as opposed to positive when $\varphi = 0.05$). With the lower value of φ, the welfare multiplier becomes positively correlated with output. When $\varphi = 0.10$, the output multiplier is slightly larger on average than when $\varphi = 0.05$, but its properties across states are roughly the same. The welfare multiplier is much larger on average. It also becomes fairly strongly negatively correlated with simulated output.

The effect of φ on the the average value of the output multiplier, albeit relatively small, makes sense in light of the intuition developed in the previous section. In particular, when φ is larger, *future* output increases by more after a positive shock to government investment because government capital is more productive. This drives a larger increase in the *current* demand for goods, which means that the price markup falls by more. In other words, the "inefficiency" effect in (48) is larger for higher values of φ. The different average sizes of the output multiplier for different values of φ affect the properties of the welfare multiplier in the following way. When the output multiplier for government investment is larger, the "inefficiency" term in the utility multiplier for government investment, (50), is larger on average. This results in a larger average welfare multiplier when φ is larger. The larger average output multiplier affects the correlation of the welfare multiplier with simulated output in the following way. Since the economy is on average highly distorted in periods in which output is low (i.e. μ is larger than average), a higher average output multiplier works to make the welfare multiplier more negatively correlated with output. We see precisely this pattern in Table 7. When $\varphi = 0.02$, the welfare multiplier for government investment is positively correlated with output. When $\varphi = 0.10$, it is negatively correlated with output.

The following conclusions can be drawn from the analysis in this section. First, the average sizes of the welfare multipliers for both types of government expenditure are sensitive to modest differences in the assumed values ϕ_G and φ. While our baseline calibrated values of these parameters seem reasonable and are in-line with the existing literature, we do not wish to take too strong a stand on the the optimal average sizes of government consumption and investment. Second, the correlation of the welfare multiplier for government consumption with simulated output is strongly positive for any reasonable value of ϕ_G. Thus, we feel comfortable in concluding, on the basis of our model, that the case for countercylical government consumption is weak. Third, the correlation of the welfare multiplier for government investment with simulated output is more sensitive to the assumed value of φ. In particular, if φ is sufficiently high, the welfare multiplier can be negatively correlated with output. With a sufficiently high value of φ, there would be a case for both larger government investment on average as well as above-average government investment during recessions.

A third exercise we consider is fixing $\nu = 1$ and setting $\varphi = 0.8$ (its baseline value). This means that government consumption enters the flow utility specification in an additively separable way. All other parameters are fixed at the posterior mode from our baseline estimation. The results are summarized in Table 8. When government consumption enters flow utility in an additively separable way, the average output multiplier is substantially smaller (0.86). Note that the output multiplier for government consumption under separability is smaller than the investment multiplier. In light of the intuition provided above, this makes sense – when government consumption does not affect the marginal utility of wealth, a government investment shock has a bigger effect on demand (because of higher future productivity), which results in a larger inefficiency term. Otherwise, the distribution of the government consumption multiplier under separability has properties similar to the investment multiplier – it varies little across states and is mildly countercyclical. The properties of the welfare multiplier under separability are similar to our baseline case – it is negative on average and strongly procyclical.

4.5 Robustness to Other Parameters

We also consider robustness of our results to a selected set of other parameters in the model. For these exercises, all but the relevant parameter(s) are set to their baseline values. We then generate the distributions of output and welfare multipliers. Results are summarized in Table 9.

We first consider the case in which the elasticities of substitution for both goods and labor are significantly higher than in our baseline by setting $\epsilon_w = \epsilon_p = 21$. Doing so makes very little difference for the properties of the output multipliers for both government consumption and investment. The distributions of the welfare multipliers for both expenditure categories are noticeably different. First, the average welfare multipliers are smaller (more negative in the case of government consumption, and less positive for government investment). This makes sense in light of the intuition developed above. When ϵ_p and ϵ_w are larger, the economy is less distorted on average. This tends to lower the welfare benefit of government expenditure.

We also consider the case in which prices and wages are perfectly flexible, i.e. $\theta_w = \theta_p = 0$. The lack of nominal rigidity results in smaller average output multipliers for both types of government expenditure, though the effect is more pronounced for the government investment shock than for government consumption. The average welfare multiplier for government investment is close to the same as in our baseline, while the average welfare multiplier for government consumption, while still negative, is actually larger. The lower output multipliers for each type of government expenditure result in welfare multipliers for both types of government expenditure becoming more positively correlated with output.

We next consider a case in which there is no variable capital utilization. We implement this by setting $\delta_2 = 1000$, which effectively results in capital utilization being fixed. This results in smaller average output multipliers for both types of government expenditure. It also results in smaller average welfare multipliers. For both types of government spending, a lack of capital utilization results in the welfare multipliers being more strongly positively correlated with output.

A final robustness exercise we consider is to lower the autoregressive parameters for government consumption and investment, setting each of these to 0.75 instead of their baseline estimated values. Less persistent shocks result in higher average output multipliers for both types of expenditure. For government consumption, this results in a larger (less negative) average welfare multiplier, and also leads to the welfare multiplier being less positively correlated with output. For government investment, the average welfare multiplier is actually smaller than in our baseline, in spite of the fact that the output multiplier is larger on average. This arises because the benefits of government investment are felt most in the future, and with a less persistent shock these future benefits are smaller.

5 Extensions

In this section, we consider several extensions related to our baseline model. In our baseline analysis we assume that all fiscal finance is through lump sum taxes. In Section 5.1, we examine different methods of fiscal finance where distortionary tax rates are positive and may react to changes in government debt. In Section 5.2 we study a situation where monetary policy is "passive" in the sense that the nominal interest rate is unresponsive to changes in government spending for several periods. One may wish to think of such a situation as approximating the effects of a binding zero lower bound. In Section 5.3, we consider a modification to our model in which a fraction of the population is "rule of thumb." Rule of thumb households do not participate in asset markets and simply consume their income each period.

5.1 Alternative Fiscal Financing Regimes

Our baseline analysis assumes that all government finance is through lump sum taxes. While highly unrealistic, this is consistent with many estimated DSGE models which abstract from distortionary taxation. As we will see, it also represents a conservative "best case" for countercyclical government expenditure.

We consider several alternative specifications concerning government finance. For all these specifications, we set the steady state values of distortionary tax rates to $\tau^C = 0.05$, $\tau^K = 0.10$, and $\tau^N = 0.20$. All other parameters are held fixed at the values assumed in our baseline simulations.[5]

[5]It is useful to emphasize that the levels of government consumption and investment are held fixed at their values

The level of steady state government debt is calibrated to be consistent with a steady state debt-GDP ratio of 0.5. The steady state value of lump sum taxes is then chosen so that the government's flow budget constraint holds in steady state.

We consider five different cases, which we call "Regimes." In Regime 1, tax rates are positive but constant, with lump sum taxes adjusting to ensure non-explosive government debt. In particular, we set $\gamma_T = 0.05$ and $\rho_T = 0.0$. In Regime 2, we assume that lump sum taxes are constant, $\gamma_T = 0.0$. We assume that all three tax rates react to deviations of debt from steady state, with $\gamma_C = \gamma_K = \gamma_N = 0.10$ and $\rho_C = \rho_K = \rho_N = 0.0$. Regime 3 is similar to 2, but we assume that tax rates react slowly to deviations of the debt-GDP ratio from steady state, with $\rho_C = \rho_K = \rho_N = 0.90$. In Regime 4, only the labor income tax adjusts to debt, with $\gamma_N = 0.30$ and $\rho_N = 0$, while $\gamma_C = \gamma_K = 0$. Regime 5 is similar, but features a delayed reaction of taxes, with $\rho_N = 0.90$ in addition to $\gamma_N = 0.30$.

We consider exactly the same quantitative exercise laid out in Section 4.1. The results are summarized in Table 10. When steady state taxes are positive but otherwise constant (Regime 1), the average output multipliers for both kinds of government expenditure are smaller than in our baseline analysis (1.00 vs. 1.06 for government consumption, and 0.900 vs. 0.903 for government investment). Smaller output multipliers are consonant with the intuition from Section 4.3, since with positive steady state tax rates the economy is more highly distorted on average. Accordingly, the average welfare multipliers for both kinds of government expenditure are smaller relative to our baseline case (-8.41 vs. -2.33 for government consumption, and 2.28 vs. 3.13 for government investment). That the welfare multipliers are lower on average also makes sense in light of the intuition developed in Section 4.3. Furthermore, when steady state tax rates are positive, both kinds of welfare multipliers are more strongly positively correlated with simulated output.

When distortionary taxes react to stabilize government debt, rather than lump sum taxes, average output multipliers are always smaller for both types of government expenditure (Regimes 2 through 5). The multipliers are smaller the more immediate are the increases in tax rates (Regimes 2 and 4) than when tax rate increases are more protracted (Regimes 3 and 5). The average welfare multipliers for both types of government expenditure are also smaller when tax rates react to stabilize debt than when lump sum taxes do the adjustment. Interestingly, average welfare multipliers for both kinds of government expenditure are lower when the tax rate increases are more delayed (Regimes 3 and 5) compared to more immediate (Regimes 2 and 4). The average welfare multiplier is negative in all cases for government consumption, and negative in all but Regime 1 for government investment. The welfare multipliers for both types of government expenditure generally become more positively correlated with simulated output when distortionary tax rates are used to finance government debt.

Our analysis with distortionary taxation reveals that our baseline case where government spending spending is financed via lump sum taxation represents a "best case." When distortionary taxes are in the model, both the output and welfare multipliers for both kinds of government expenditure are

from our baseline simulations. Because positive distortionary taxes lower steady state output, this means that the ratios of government consumption and investment to output are higher than assumed in our baseline simulations.

smaller. Furthermore, the welfare multipliers become even more positively correlated with simulated output than in our baseline case. The implication of this finding is that the case for countercylical government expenditure is made weaker by the realistic inclusion of distortionary tax finance.

5.2 Passive Monetary Policy

Much of the renewed interest in fiscal policy stems from the recent period of low, zero, or even negative interest rates in the US and other developed nations. Previous research has demonstrated that government spending might be substantially more effective in stimulating output in regimes in which interest rates do not adjust to changes in government spending – see, for example, Krugman (1998), Eggertson and Woodford (2003), or Christiano, Eichenbaum and Rebelo (2011).

In this section we analyze the effects of passive monetary for the size and state-dependence of the output and welfare multipliers. We simulate the effects of a passive monetary regime by assuming that the nominal interest rate is, in expectation, pegged at its most recent value for a number of periods, after which time it reverts to following the Taylor rule specified above, (27). Formally, such a policy is characterized by:

$$E_t i_{t+q} = \begin{cases} i_{t-1} & \text{if } q < Q \\ (1-\rho_i)i + \rho_i i_{t+q-1} + (1-\rho_i)\left[\phi_\pi \pi_{t+q} + \phi_y(\ln Y_{t+q} - \ln Y_{t+q-1})\right] + s_i e_{i,t+q} & \text{if } q \geq Q \end{cases} \tag{52}$$

In this specification Q is the number of periods for which the interest rate is expected to be pegged at its most recent value. We assume that the expected duration of peg is exogenous and known by all agents. Our implementation of an interest rate peg is based on Laseen and Svensson (2011). In particular, we resolve the model where the Taylor rule is augmented by $Q-1$ anticipated shocks. These have the flavor of "news shocks" in that agents observe them prior to their effect on policy. Formally:

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\left[\phi_\pi \pi_t + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_i \varepsilon_{i,t} + \sum_{q=1}^{Q-1} \varepsilon_{i,q,t-q} \tag{53}$$

In (53), $\varepsilon_{i,q,t}$ is a shock to the Taylor rule observed by agents in period t which does not affect the policy rule until q periods into the future. One can think about these $Q-1$ shocks as "forward guidance shocks" as in Del Negro, Giannoni and Patterson (2012). It is important to note that these shocks are fully observed by agents. We implement an interest rate peg as follows. Given a shock to government consumption or investment, we solve for the values of the current monetary policy shock, $\varepsilon_{i,t}$, and the $Q-1$ "forward guidance shocks" which are required for the interest rate to remain unchanged for Q periods. Because agents observe the "forward guidance shocks," they fully anticipate that the nominal interest rate will be pegged for Q periods. Our exercise described here therefore consists of examining the responses of output and welfare to a government spending shock to which the nominal interest rate does not react (in expectation) for Q periods.

While it is natural to think about passive monetary policy as embodied in an interest rate peg as approximating the effects of a binding zero lower bound, it is important to emphasize that our model does not explicitly incorporate a binding floor on nominal interest rates. Conditional on particular realizations of "forward guidance shocks," agents may expect the nominal interest rate to remain fixed going forward into the future. But since these forward guidance shocks are i.i.d., agents do not, for example, anticipate that monetary policy may soon become passive in states where the nominal interest rate is low. Further, our approach assumes that the duration of an interest rate peg is known and exogenous, which would not be the case in a fully non-linear solution methodology. Our model features far too many state variables for it to be feasible to adopt a fully global solution methodology. Fernández-Villaverde, Gordon, Guerrón-Quintana and Rubio-Ramirez (2015) consider a fully non-linear solution of a textbook New Keynesian model without capital. While their model is simpler than ours and their solution methodology more complex, some of our results about state-dependence in a passive monetary policy regime echo their findings.

We re-solve the model at the posterior mode of the parameters from our baseline estimation, replacing the standard Taylor rule with (53). When re-solving the model, the standard deviation of the forward guidance shocks are all set to 0. This means that the properties of the re-solved model are identical to our baseline model, with the exception that we generate decision rules for the reaction to forward-guidance shocks. We generate 10,000 different states by simulating the model (starting from the non-stochastic steady state and dropping the first 100 periods as a burn-in). These simulated states are identical to those used in our baseline simulations. Then at each simulated state, we compute impulse responses to a government expenditure shock (either government consumption or investment) and a simultaneous sequence of current and anticipated monetary policy rule shocks, where the size of the monetary shocks is chosen so as to keep the nominal interest rate fixed (in expectation) at its most recent value for the desired number of periods. For the exercises reported in the paper, we consider peg lengths of 4 and 8 quarters.

To develop a better sense for how a passive monetary policy stance impacts the dynamic effects of government expenditure shocks, Figure 3 plots impulse responses of the interest rate (left column) and output (right column) to both government consumption shocks (upper row) and investment shocks (lower row). These impulse responses are computed where the initial state is the non-stochastic steady state. The solid lines plot responses in our baseline case where monetary policy obeys the standard Taylor rule. The dashed lines plot responses when the interest rate is pegged for four periods, while the dotted lines plot responses when the interest rate is pegged for eight periods in expectation. The output responses at each horizon are scaled by the inverse impact response of the relevant government expenditure category so that these responses are displayed in "multiplier form." By construction, the nominal interest rate does not react to a government expenditure shock for the specified number of periods, after which time it increases.[6] Output

[6]Note that, unlike the simplest version of a textbook New Keynesian model with a non-inertial Taylor Rule or strict inflation targeting, the response of the nominal interest rate subsequent to the conclusion of the peg is not identical to the response under the Taylor rule. This feature arises because our Taylor rule features interest smoothing and other endogenous state variables.

responds more to either kind of government expenditure shock when the interest rate is pegged, and the higher output response persists even after the "liftoff" from the peg. Under a four period peg, the impact output multipliers when the initial state is the non-stochastic steady state are about 1.2 for government consumption and 1 for government investment. Under an eight period peg, these multipliers are much larger – 2.3 for government consumption and 1.8 for government investment.

The results from our simulation exercises are summarized in Table 11. When the nominal interest rate is pegged for four quarters, the average output multipliers for both government consumption and investment are higher than when monetary policy is governed by a conventional Taylor rule. In particular, the average output multiplier for government consumption is 1.23 (compared to 1.06 under a Taylor rule) and the average output multiplier for government investment is 1.03 (compared to 0.90 under a Taylor rule). The output multiplier for government consumption is slightly more volatile across states under the interest rate peg than a Taylor rule, while the output multiplier for government investment is about as volatile as under a Taylor rule. The welfare multipliers for both types of government expenditure are larger on average than when monetary policy is governed by a Taylor rule. This is intuitive in light of our discussion in Section 4.3. The welfare multiplier for government consumption is still negative on average, but is less positively correlated with simulated output than under a Taylor rule (correlation with simulated output of 0.29 instead of 0.50). The welfare multiplier for government investment is more positive on average than under a Taylor rule, and is now mildly negatively correlated with simulated output instead of uncorrelated with output.

The differences relative to our baseline case are accentuated when the nominal interest rate is pegged for eight quarters instead of four. The average output multiplier for government consumption is 2.34 and the average output multiplier for government investment is 1.77. These multipliers are significantly more volatile across states than under a Taylor rule. Accordingly, the welfare multipliers for both types of government expenditure are larger than either under a four period interest rate peg or a Taylor rule, although the welfare multiplier for government consumption is still negative on average. The welfare multipliers are also substantially more volatile across states when the interest rate is pegged for eight periods. Both welfare multipliers are now strongly negatively correlated with simulated output. Given the intuition developed in Section 4.3, this also makes sense – we would expect the welfare multiplier to be more negatively correlated with output the larger is the output multiplier.

When monetary policy is passive, the average welfare multipliers for both kinds of government expenditure shocks are larger than under a Taylor rule. This result echoes the conclusions in Christiano et al. (2011) and Nakata (2013) that increasing government expenditure is relatively more desirable during periods of passive monetary policy. Our analysis contributes to their conclusions in the following ways. First, we jointly examine the output and welfare effects of both government consumption and investment shocks under passive monetary policy, whereas these papers focus only on government consumption. Second, we find that output multipliers vary significantly across states for both kinds of government expenditure shocks for sufficiently long peg periods. This suggests that some caution might be in order when using linear approximations, a point emphasized in Fernández-Villaverde et al. (2015) and Braun, Körber and Waki (2012). Third, an important difference relative to our baseline result is that the welfare multipliers for both kinds of government expenditure become less positively, and potentially negatively, correlated with output when the interest rate is pegged. Since monetary policy is most likely to be passive in a period of depressed output, this suggests that such times may be particularly attractive times to increase government expenditure.

5.3 Rule of Thumb Households

In our baseline model, all households have free access to credit markets and can save by accumulating physical capital. In this setup, consumption depends on the present discounted value of income, not current just current income. The forward-looking nature of consumption limits the extent to which "old Keynesian" multiplier effects for government expenditure might matter.

In this section, we consider an extension of our model to include a fraction of households who do not participate in credit or capital markets. Following the early contribution of Campbell and Mankiw (1989) and its more recent inclusion into an otherwise textbook New Keynesian model by Galí, López-Salido and Vallés (2007), we refer to these households as "rule of thumb consumers." As in our baseline model, there are a continuum of households. We assume that a fraction $\Phi \in [0,1]$ engage in rule of thumb behavior, whereas the fraction $1 - \Phi$ behave solve the standard dynamic optimization problem laid out in Section 3.1.2. In the text, we only discuss features of the model relevant to the rule of thumb population, which we shall hereafter abbreviate as the ROT population. We will refer to the remainder of the population as optimizing households. We shall demarcate variables chosen by ROT households with a r subscript, and variables pertaining to the optimizing households with an o subscript. The full set of equilibrium conditions is available in Appendix D.

The ROT households have identical preferences to the optimizing households, as defined above in (7) and (8). These households do not hold government debt, do not accumulate physical capital, and do not have an ownership stake in firms. We also assume that they do not have any power in wage-setting. Rather, they supply labor at the aggregate real wage determined by the behavior of optimizing households. We assume that households of both types face the same distortionary tax rates, but potentially pay different lump sum taxes. The flow budget constraint for the ROT households is:

$$(1 + \tau_t^C) C_{r,t} = (1 - \tau_t^N) w_t N_{r,t} - T_{r,t} \tag{54}$$

Here, $T_{r,t}$ is the lump sum tax levied against ROT households. The solution to the ROT optimization problem is a conventional static labor supply curve of the form:

$$\upsilon_t \xi_t N_{r,t}^{\chi} = \lambda_{r,t} (1 - \tau_t^N) w_t \tag{55}$$

In (55), $\lambda_{r,t}$ is the marginal utility of wealth for ROT households. υ_t and ξ_t are preference shocks common to both types of households. In equilibrium, aggregate variables are simply the weighted sums of variables pertaining to optimizing and ROT households, respectively. In particular, we have:

$$N_t = (1-\Phi)N_{o,t} + \Phi N_{r,t} \tag{56}$$

$$C_t = (1-\Phi)C_{o,t} + \Phi C_{r,t} \tag{57}$$

$$\widehat{K}_t = (1-\Phi)\widehat{K}_{o,t} \tag{58}$$

$$I_t = (1-\Phi)I_{o,t} \tag{59}$$

Aggregate capital services and investment are only proportional to the capital services and investment of optimizing households because ROT households do not hold any physical capital. The aggregate production function and aggregate resource constraint are identical to our baseline model.

For the exercises described in this section, we assume that the government finances its expenditure solely with lump sum taxes. Because of the presence of ROT households, the timing and distribution across households of these lump sum taxes are no longer irrelevant, as would be the case in our baseline model. To simplify matters to the greatest extent possible, we assume that the government balances its budget each period, so $T_t = G_t + G_{I,t}$. We assume that aggregate lump sum taxes are levied proportionally to population shares, so that $T_{r,t} = \Phi\left(G_t + G_{I,t}\right)$ and $T_{o,t} = (1-\Phi)\left(G_t + G_{I,t}\right)$. There are numerous different ways for the government to finance its expenditure that might be relevant with a ROT population. In the interest of space, we focus only on this one in the paper.

We conduct the same simulation exercises as in our baseline. We do not re-estimate the parameters of the model, instead using the posterior mode of our baseline estimation. We consider two alternative values of the share of ROT households, $\Phi = 0.25$ and $\Phi = 0.50$. We report welfare multipliers for each type of household individually, as well as an aggregate welfare multiplier, defined to equal the population-weighted sum of welfare for each type of household. The results from our simulation exercises are presented in Table 12.

We find that the average output multiplier for government consumption is increasing in the share of ROT households, while the average output multiplier for government investment is decreasing in Φ. The effects of the parameter Φ on the average output multiplier for either type of government expenditure are nevertheless not quantitatively large.[7] The aggregate welfare multipliers for both types of government expenditures look fairly similar to our baseline case. When $\Phi = 0.25$, the average welfare multiplier for government consumption is -2.02 and is strongly positively correlated with output, while the average welfare multiplier for government investment is 2.79 and is uncorrelated

[7] This result may seem surprising. It arises because we assume that ROT households have identical preferences as optimizing households. In particular, both types of households have the same habit formation parameter, which we estimate to be fairly high (although well within the range of conventional estimates). This high degree of habit formation mutes the impact of current income on current consumption for ROT households. If we re-solve the model assuming that ROT households do not have habit formation, there is a much larger effect of the parameter φ on the average magnitudes of the output multipliers.

with simulated output. For both types of expenditure, the average aggregate welfare multipliers for both types of government expenditure are slightly larger, and the correlations of the welfare multipliers with simulated output are slightly smaller. when the ROT population share is 50 percent instead of 25 percent.

In spite of the broad similarities relative to our baseline with the aggregate welfare multipliers, there are interesting differences when the welfare multipliers are broken down by type of household. For both types of government expenditure, the average welfare multipliers are larger for ROT households than optimizing households. This suggests that ROT households would prefer higher average levels of government consumption and investment than would optimizing households. This result is, of course, dependent on the way in which the government finances its expenditure. Particularly when the ROT population is small, our assumed fiscal finance structure effectively involves a transfer from optimizing households to ROT households. This is because both types of households benefit from aggregate government consumption and capital, but pay taxes proportional to their population shares. In spite of these distributional differences in the size and magnitudes of the average welfare multipliers, the correlations of household-specific welfare multipliers with simulated output are broadly similar to our baseline analysis. The welfare multiplier for government consumption for both household types is positively correlated with simulated output, and the welfare multipliers for government investment are either close to uncorrelated or mildly negatively correlated with output.

6 Conclusion

The objective of this paper has been to explore the output and welfare effects of government expenditure shocks. We do so in the context of an otherwise canonical DSGE model, augmented to include both government consumption and investment. Within the context of this model, we address several questions. How large are the output multipliers for government consumption and investment on average? Do these multipliers vary across states of the business cycle? If so, how? What are signs and magnitudes of the average welfare multipliers for both types of government expenditure? How do the welfare multipliers vary across states of the business cycle? Is countercyclical government expenditure desirable? How are the answers to all of these questions impacted by the nature of fiscal finance and the stance of monetary policy?

Broadly, speaking, our results have the following normative implications. First, the average size of government consumption may be too high, and the size of government investment too low, relative to what would be optimal. Second, when monetary policy is active, there is not a compelling case for countercyclical government expenditure – the welfare multiplier for government consumption is strongly positively correlated with output, while the welfare multiplier for government investment is uncorrelated with output. Third, the presence of distortionary tax finance weakens any case for counteryclical government expenditure. Fourth, these implications are potentially different when monetary policy is passive, such as at the zero lower bound. The welfare multipliers for both types of government expenditure are larger when monetary policy is passive, and the welfare multipliers may be negatively correlated with simulated output.

We conclude by reiterating the caveat than any normative implications are dependent on the structure of our model. We have not sought to write down a model to deliver particular results, but rather to study the output and welfare effects of government expenditure shocks in an otherwise canonical framework. A different model could very well yield different normative implications. Our quantitative results, and the analytic intuition we provide for them, could be of use to researchers interested in developing models of state-dependent fiscal multipliers or models in which it is desirable to engage in countercylical government spending.

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Table 1: Calibrated Parameters

Parameter	Value or Target	Description
β	0.995	Discount factor
α	1/3	Capital's share
δ_0	0.025	Steady state depreciation
δ_1	$u^* = 1$	Utilization linear term
δ_G	0.025	Government capital depreciation
F	$\Pi^* = 0$	Fixed cost
ξ	$N = 1/3$	Labor disutility
ϵ_p	11	Elasticity sub goods
ϵ_w	11	Elasticity sub labor
G	$\frac{G}{Y} = 0.1524$	Steady state gov. consumption
G_I	$\frac{G_I}{Y} = 0.043$	Steady state gov. investment
A	$AK_G^{\varphi} = 1$	Steady state productivity
ϕ_G	0.8	Utility weight on private consumption
φ	0.05	Government capital parameter

Notes: this table lists the values of calibrated parameters or the target used in the calibration.

Table 2: Parameter Estimates

			Posterior			
Parameter	Description	Prior	Mode	S.E.	Mean	Median
b	Habit formation	B $[0.6, 0.1]$	0.7220	0.0603	0.7556	0.7559
ν	Elasticity of sub, C and G	G $[0.5, 0.3]$	0.2850	0.1251	0.3469	0.3103
θ_w	Wage stickiness	B $[0.7, 0.1]$	0.4992	0.0999	0.5532	0.5602
θ_p	Price stickiness	B $[0.7, 0.1]$	0.7092	0.0397	0.7207	0.7221
ζ_w	Wage indexation	B $[0.5, 0.15]$	0.3982	0.1668	0.4451	0.4384
ζ_p	Price indexation	B $[0.5, 0.15]$	0.0891	0.0432	0.1142	0.1073
χ	Inverse Frisch elasticity	G $[2, 0.75]$	1.2734	0.5291	1.5340	1.4510
κ	Inv. adjustment cost	G $[4, 2]$	5.0008	1.6421	5.8852	5.6963
δ_2	Utilization adjust cost	N $[0.1, 0.1]$	0.0361	0.0179	0.0560	0.0459
ϕ_π	TR inflation	N $[1.7, 0.3]$	2.1403	0.2043	2.1322	2.1265
ϕ_y	TR output growth	N $[0.125, 0.05]$	0.2098	0.0475	0.2069	0.2074
ρ_i	TR smoothing	B $[0.6, 0.1]$	0.8194	0.0203	0.8204	0.8213
ρ_A	AR productivity	B $[0.6, 0.1]$	0.8948	0.0236	0.8878	0.8893
ρ_Z	AR investment	B $[0.6, 0.1]$	0.7042	0.0812	0.6682	0.6721
ρ_v	AR intertemporal preference	B $[0.6, 0.1]$	0.7292	0.0799	0.6904	0.6969
ρ_ξ	AR labor supply	B $[0.6, 0.1]$	0.8085	0.0750	0.7215	0.7272
ρ_G	AR gov. consumption	B $[0.6, 0.1]$	0.9397	0.0146	0.9361	0.9369
ρ_{IG}	AR gov. investment	B $[0.6, 0.1]$	0.9364	0.0153	0.9338	0.9346
s_i	SD TR shock	IG $[0.005, 0.01]$	0.0013	0.0001	0.0013	0.0013
s_A	SD productivity shock	IG $[0.005, 0.01]$	0.0044	0.0003	0.0045	0.0045
s_Z	SD investment shock	IG $[0.005, 0.01]$	0.0442	0.0149	0.0542	0.0517
s_v	SD intertemporal preference shock	IG $[0.005, 0.01]$	0.0231	0.0049	0.0249	0.0247
s_ξ	SD labor supply shock	IG $[0.005, 0.01]$	0.0875	0.0492	0.1868	0.1644
s_G	SD gov. consumption shock	IG $[0.005, 0.01]$	0.0077	0.0006	0.0079	0.0079
s_{IG}	SD gov. investment shock	IG $[0.005, 0.01]$	0.0172	0.0012	0.0175	0.0174

Notes: this table presents the prior and posterior distributions for estimated parameters. "B" stands for a beta distribution, "N" for normal, "G" for gamma, and "IG" for inverse gamma. The first term in the brackets is the prior mean, and the second term is the prior standard deviation. The posterior is generated with 1,000,000 Metropolis Hastings draws with an acceptance rate of 20 percent. The log posterior evaluated at the mode is -2735.15.

Table 3: Steady State Output and Welfare Multipliers

	Multiplier
Consumption	
Output	1.0657
Welfare	-2.4105
Cons Eq	-0.1670
Investment	
Output	0.9046
Welfare	3.1759
Cons Eq	0.3260

Note: This table shows output, welfare, and consumption equivalent welfare multipliers for both government consumption and investment shocks when the initial state is the non-stochastic steady state.

Table 4: Output and Welfare Multipliers from Simulations

Consumption	Mean	SD	Min	Max	Corr w/ Output
Output	1.0662	0.0169	1.0086	1.1311	0.2709
Welfare	-2.3322	1.5831	-7.6967	3.8501	0.4998
Cons Eq	-0.1413	0.0947	-0.2905	0.3422	0.4505
Investment	Mean	Std Dev	Min	Max	Corr w/ Output
Output	0.9031	0.0042	0.8845	0.9170	-0.2868
Welfare	3.1291	0.6226	0.0052	5.4704	-0.0041
Cons Eq	0.3217	0.0246	0.0008	0.3860	-0.0800
		Mean Recession Mults			
		Output	Welfare	Cons Eq	% of Pos/Neg Welf Mults
Consumption		1.0600	-3.4088	-0.1907	7.03%
Investment		0.9048	3.1464	0.3251	0.00%

Note: the numbers in this table are moments from the distribution of output and welfare multipliers to both government consumption and investment shocks. The moments are generated by first simulating 10,100 periods of the model starting from the non-stochastic steady state. After dropping the first 100 periods as a burn-in, we compute impulse responses to one standard deviation government consumption and investment shocks at each simulated value of the state vector. The impulse responses form the basis of the multiplier definitions as described in the text. The consumption equivalent welfare multipliers are constructed by numerically calculating how much consumption households would need to be given (or have taken away) in the period of the shock to generate the same change in welfare.

Table 5: Average Multipliers in Shock-Specific Recessions

	Productivity	Investment	Savings	Labor Supply	Monetary Policy
Consumption					
Output	1.0592	1.0718	1.0596	1.0642	1.0888
Welfare	-3.0657	-2.8184	-2.2758	-2.4449	-5.9829
Cons Eq	-0.1853	-0.1781	-0.1574	-0.1633	-0.2628
Investment					
Output	0.9043	0.9076	0.9032	0.9044	0.9191
Welfare	2.9508	3.2488	3.1324	3.2048	0.3760
Cons Eq	0.3180	0.3279	0.3230	0.3264	0.0949

Note: This table shows the average values of multipliers in typical recessions conditional on an exogenous shock listed in columns. The exact exercise used to construct this table is described in the text.

Table 6: Parameter Estimates: Alternative Calibrated Values of ϕ_G or φ

	Posterior Mode			
Parameter	$\phi_G = 0.7$	$\phi_G = 0.9$	$\varphi = 0.02$	$\varphi = 0.10$
b	0.7203	0.7167	0.7204	0.7248
ν	0.3748	0.1734	0.2795	0.2945
θ_w	0.4993	0.4936	0.4985	0.5008
θ_p	0.7093	0.7084	0.7085	0.7105
ζ_w	0.3981	0.3974	0.3972	0.3998
ζ_p	0.0890	0.0891	0.0890	0.0892
χ	1.2827	1.2464	1.2848	1.2553
κ	4.9987	4.9814	5.0404	4.9460
δ_2	0.0361	0.0361	0.0352	0.0374
ϕ_π	2.1409	2.1380	2.1406	2.1399
ϕ_y	0.2098	0.2102	0.2101	0.2093
ρ_i	0.8195	0.8186	0.8193	0.8196
ρ_A	0.8947	0.8947	0.8939	0.8970
ρ_Z	0.7048	0.7023	0.7051	0.7030
ρ_v	0.7301	0.7355	0.7299	0.7282
ρ_ξ	0.8093	0.8100	0.8106	0.8051
ρ_G	0.9398	0.9395	0.9396	0.9398
ρ_{IG}	0.9364	0.9364	0.9362	0.9366
s_i	0.0013	0.0013	0.0013	0.0013
s_A	0.0044	0.0044	0.0044	0.0044
s_Z	0.0441	0.0442	0.0445	0.0438
s_v	0.0232	0.0223	0.0232	0.0229
s_ξ	0.0878	0.0840	0.0872	0.0880
s_G	0.0077	0.0077	0.0077	0.0077
s_{IG}	0.0172	0.0172	0.0172	0.0172

Notes: this table shows the posterior mode for estimated parameters when ϕ_G or φ are calibrated at different values. All but the listed parameter in the relevant column are calibrated at their benchmark values listed in Table 1. Prior distributions for estimated parameters are the same as listed in Table 2.

Table 7: Simulation Results with Different ϕ_G, ν, or φ

	Government Consumption				
	Mean	SD	Min	Max	Corr w/ Output
ϕ_G = 0.7					
Output	1.0743	0.0127	1.0298	1.1216	0.2273
Welfare	11.3412	0.4259	5.6950	17.2732	0.4259
Cons Eq					
ϕ_G = 0.9					
Output	1.0596	0.0292	0.9588	1.1759	0.3331
Welfare	-14.4753	1.6708	-19.5839	-7.7459	0.5524
Cons Eq					
	Government Investment				
	Mean	SD	Min	Max	Corr w/ Output
φ = 0.02					
Output	0.8898	0.0039	0.8733	0.9018	-0.2267
Welfare	-11.9815	0.5986	-14.9439	-10.2986	0.3672
Cons Eq					
φ = 0.10					
Output	0.9291	0.0049	0.9076	0.9465	-0.3007
Welfare	28.6282	1.4006	23.3640	34.4365	-0.3035
Cons Eq					

Note: this table is constructed similarly to Table 4, but assumes different values of ϕ_G or φ. For the different assumed values of ϕ_G or φ, other parameters are re-estimated as in Table 6.

Table 8: Simulation Results with Different ν

	Government Consumption				
	Mean	SD	Min	Max	Corr w/ Output
ϕ_G = 0.8, ν = 1					
Output	0.8608	0.0042	0.8446	0.8743	-0.2335
Welfare	-2.2783	0.6285	-4.7952	-0.0521	0.4869
Cons Eq	-0.1792	0.0266	-0.2590	-0.0097	0.4688

Note: this table is constructed similarly to Table 4, but fixed the parameter ν = 1 (and assumed ϕ_G = 0.8). Other parameters are held fixed at the posterior mode from our baseline estimation.

Table 9: Other Parameter Robustness

	Consumption					*Investment*				
	Mean	SD	Min	Max	Corr w/ Output	Mean	SD	Min	Max	Corr w/ Output
$\epsilon_w = \epsilon_p = 21$										
Output	1.0609	0.0161	1.0060	1.1220	0.2571	0.9067	0.0055	0.8840	0.9266	-0.1631
Welfare	-5.1631	1.5554	-10.9875	0.7056	0.4645	0.6308	0.8354	-4.4178	2.9129	-0.1531
Cons Eq										
$\theta_w = \theta_p = 0$										
Output	1.0420	0.0213	0.9695	1.1322	0.3636	0.8229	0.0089	0.7908	0.8550	-0.4431
Welfare	-1.3362	1.6606	-6.8109	5.1058	0.5769	3.1440	0.5307	1.1730	5.2930	0.3528
Cons Eq										
$\delta_2 = 1000$										
Output	1.0152	0.0160	0.9587	1.0776	0.4049	0.8673	0.0048	0.8458	0.8845	-0.1707
Welfare	-3.3958	1.7335	-9.3521	3.5679	0.6350	2.5579	0.7342	-1.2058	4.9804	0.2028
Cons Eq										
$\rho_G = \rho_{G_I} = 0.75$										
Output	1.1815	0.0162	1.1182	1.2450	0.4687	0.9696	0.0021	0.9611	0.9771	0.1992
Welfare	-0.3649	0.6337	-3.9029	1.6217	0.2687	1.1271	0.3653	-1.3179	2.0145	-0.0946
Cons Eq										

Note: this table is structured similar to Table 4, but fixes the listed parameter values at different values than those used in our baseline simulations. All other parameter values other than the ones listed in the relevant rows are set to their baseline values.

Table 10: Alternative Fiscal Financing Regimes

	Consumption					*Investment*				
	Mean	SD	Min	Max	Corr w/ Output	Mean	SD	Min	Max	Corr w/ Output
Regime 1										
Output	1.0049	0.0136	0.9605	1.0591	0.3035	0.9005	0.0040	0.8831	0.9134	-0.3096
Welfare	-8.4057	1.5112	-13.3440	-2.5430	0.5682	2.2845	0.6329	-0.8367	4.6284	0.1183
Cons Eq	-0.2663	0.0201	-0.3220	-0.1558	0.5415	0.2420	0.0334	-0.0704	0.3146	0.0599
Regime 2										
Output	0.9722	0.0143	0.9234	1.0291	0.2467	0.8514	0.0062	0.8256	0.8708	-0.3240
Welfare	-9.5185	1.5353	-14.5544	-3.6130	0.5636	-2.9373	0.7917	-6.5220	-0.5080	0.4072
Cons Eq	-0.2818	0.0180	-0.3325	-0.1877	0.5297	-0.1578	0.0214	-0.2304	-0.0580	0.3621
Regime 3										
Output	0.9900	0.0152	0.9403	1.0525	0.3858	0.8846	0.0051	0.8631	0.9005	-0.2294
Welfare	-15.6119	1.9336	-21.9958	-8.2243	0.6784	-3.1220	0.8160	-6.8990	-0.5633	0.4611
Cons Eq	-0.3498	0.0156	-0.3967	-0.2759	0.6531	-0.1631	0.0211	-0.2367	-0.0625	0.4201
Regime 4										
Output	0.9347	0.0165	0.8803	1.0017	0.3705	0.8260	0.0061	0.7981	0.8442	-0.2500
Welfare	-16.7292	1.9883	-23.6838	-9.1963	0.6528	-4.4941	0.8304	-8.2190	-1.9721	0.4126
Cons Eq	-0.3603	0.0152	-0.4086	-0.2902	0.6241	-0.1979	0.0159	-0.2570	-0.1380	0.3467
Regime 5										
Output	0.9800	0.0158	0.9287	1.0456	0.4817	0.8719	0.0042	0.8513	0.8856	0.0187
Welfare	-17.1460	2.0785	-24.5084	-9.3625	0.6928	-4.9749	0.8848	-8.7144	-2.2259	0.5457
Cons Eq	-0.3640	0.0156	-0.4146	-0.2926	0.6706	-0.2082	0.0157	-0.2643	-0.1475	0.4992

Note: this table is structured similar to Table 4, but considers five different distortionary tax regimes. For all five regimes steady state distortionary tax rates are set to $\tau^C = 0.05$, $\tau^K = 0.10$, and $\tau^N = 0.20$. In Regime 1, distortionary tax rates are fixed, with lump sum taxes adjusting so as to stabilize debt (with $\gamma_T = 0.05$ and $\rho_T = 0$). For Regimes 2-5, lump sum taxes are fixed. In Regime 2, we assume $\gamma_C = \gamma_N = \gamma_K = 0.1$ with $\rho_C = \rho_N = \rho_K = 0$. Regime 3 is similar, but sets $\rho_C = \rho_N = \rho_K = 0.90$. In Regime 4, we assume that $\gamma_N = 0.30$, with $\gamma_N = \gamma_K = 0$ and $\rho_N = 0$. Regime 5 is similar, but sets $\rho_N = 0.90$.

Table 11: Passive Monetary Policy

	Consumption			*Investment*		
	Mean	SD	Corr w/ Output	Mean	SD	Corr w/ Output
Four Quarter Peg						
Output	1.2348	0.0215	0.4152	1.0342	0.0037	0.5614
Welfare	-2.0470	1.6881	0.2921	3.3783	0.9218	-0.2309
Cons Eq						
Eight Quarter Peg						
Output	2.3439	0.1537	0.7545	1.7667	0.0952	0.6929
Welfare	-1.2155	5.2254	-0.3549	4.4333	3.5837	-0.4699
Cons Eq						

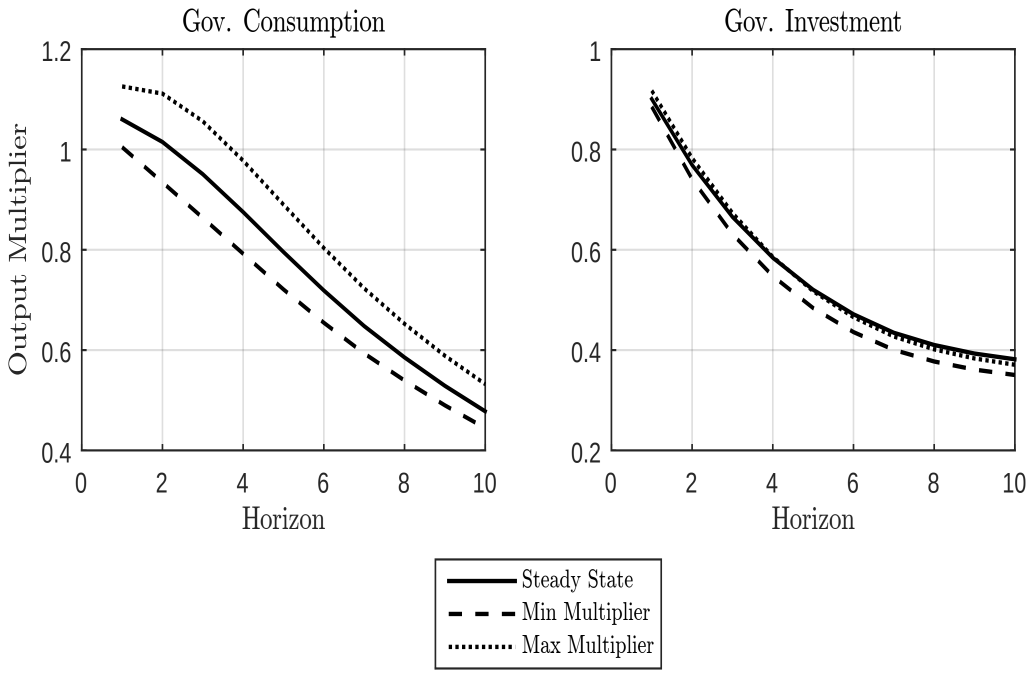
Note: this table presents moments from the distributions of multipliers when the nominal interest rate is pegged in expectation for four or eight quarters. The states from which these multipliers are generated are identical to our baseline case. The only difference here is that when there is a government expenditure shock, the nominal interest rate is unresponsive for either four or eight quarters, after which time the nominal interest rate is set according to the standard Taylor rule.

Table 12: Rule of Thumb Household

	Consumption			*Investment*		
	Mean	SD	Corr(Ysim)	Mean	SD	Corr(Ysim)
Rule-of-Thumb Pop = 25%						
Output	1.0843	0.0178	0.3516	0.9019	0.0045	-0.2230
Optimizer						
Welfare	-5.1703	1.7869	0.4909	0.2712	0.7439	0.0130
Cons Eq	-0.2350	0.0453	0.4632	0.0697	0.1084	0.0098
Rule-of-Thumb						
Welfare	7.4288	0.9519	0.4094	10.3599	0.5064	-0.0301
Cons Eq	0.4761	0.0191	0.2607	0.5301	0.0091	-0.3622
Weighted Avg						
Welfare	-2.0205	1.5507	0.4870	2.7934	0.6400	0.0054
Cons Eq	-0.1255	0.1038	0.4403	0.3093	0.0294	-0.0611
Rule-of-Thumb Pop = 50%						
Output	1.0979	0.0195	0.4244	0.8954	0.0054	-0.1542
Optimizer						
Welfare	-2.2065	2.0599	0.4265	-0.5758	1.0189	-0.0579
Cons Eq	-0.1160	0.1297	0.3958	-0.0302	0.1035	-0.0531
Rule-of-Thumb						
Welfare	-0.2925	0.9585	0.4535	6.4555	0.4713	0.0478
Cons Eq	-0.0011	0.1365	0.4364	0.4557	0.0109	-0.2366
Weighted Avg						
Welfare	-1.2495	1.4714	0.4463	2.9399	0.6661	-0.0274
Cons Eq	-0.0746	0.1264	0.4174	0.3152	0.0298	-0.0933

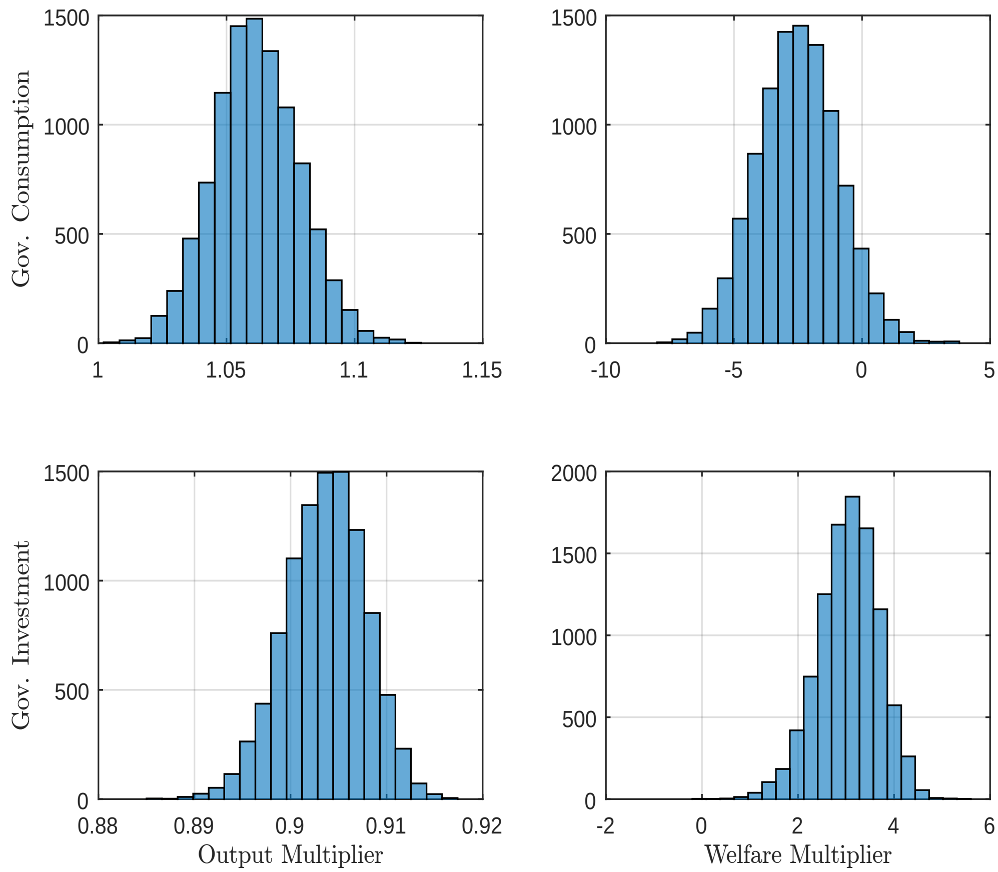
Note: this table presents moments from the distribution of multipliers for rule of thumb populations of $\Phi = 0.25$ and $\Phi = 0.50$. The weighted average multiplier computes aggregate welfare as the population-weighted average of welfare of each type of agent.

Figure 1: Output Impulse Responses to Government Consumption and Investment Shocks



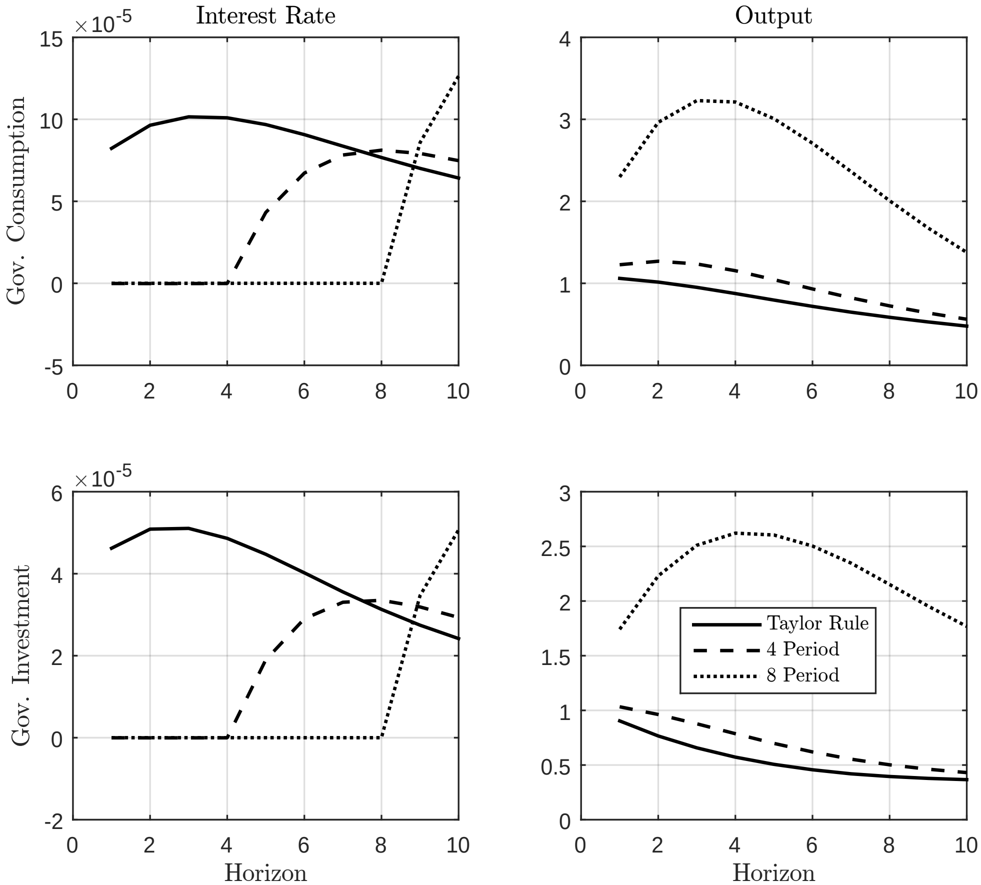
Note: this figure plots impulse responses of output to a government consumption shock (left column) and government investment shock (right column). These responses are constructed beginning from three different initial states – the non-stochastic steady state (solid line), the state generating the smallest output multiplier (dashed line), and the state generating the largest output multiplier (dotted line). The output responses at each horizon are scaled by the inverse of the response of the relevant government expenditure category on impact so as to express the responses in "multiplier form."

Figure 2: Histograms of Output and Welfare Multipliers, Government Consumption and Investment Shocks



Note: this figure plots histograms of the output multiplier (left column) and welfare multiplier (right column) to both government consumption shocks (upper row) and government investment shocks (bottom row).

Figure 3: Output and Interest Rate Responses under Interest Rate Peg



Note: this figure plots impulse responses of both the nominal interest rate (left column) and output (right column) to government consumption (upper row) and government investment (lower row) shocks. These responses are generated assuming that the initial state is the non-stochastic steady state. The solid lines correspond to the responses under the conventional Taylor rule. The dashed and dotted lines, respectively, correspond to interest rate pegs of four and eight quarters. The output responses at each horizon are scaled by the inverse of the impact response of the relevant government expenditure category so as to express these responses in "multiplier form."

A Equilibrium Conditions of the Medium Scale DSGE Model

This Appendix lists the full set of equilibrium conditions for the model of Section 3.

A.1 Household Optimality Conditions

The optimality conditions for the household problem described in Subsection 3.1.2 are:

$$(1+\tau_t^C)\lambda_t = \upsilon_t \frac{1}{\widehat{C}_t}\phi_G(C_t - bC_{t-1})^{-\frac{1}{\nu}} - \beta b E_t \upsilon_{t+1}\frac{1}{\widehat{C}_{t+1}}\phi_G(C_{t+1}-bC_t)^{-\frac{1}{\nu}} \tag{A.1}$$

$$\widehat{C}_t = \phi_G\left(C_t - bC_{t-1}\right)^{\frac{\nu-1}{\nu}} + (1-\phi_G)G_t^{\frac{\nu-1}{\nu}} \tag{A.2}$$

$$(1-\tau_t^K)\lambda_t R_t = \mu_t\left(\delta_1 + \delta_2(u_t - 1)\right) \tag{A.3}$$

$$\lambda_t = \mu_t Z_t\left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] + \beta E_t \mu_{t+1} Z_{t+1}\kappa\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{A.4}$$

$$\mu_t = \beta E_t \lambda_{t+1}(1-\tau_{t+1}^K)R_{t+1}u_{t+1} + \beta E_t \mu_{t+1}\left(1 - \delta_0 - \delta_1(u_{t+1}-1) - \frac{\delta_2}{2}(u_{t+1}-1)^2\right) \tag{A.5}$$

$$\lambda_t = \beta(1+i_t)E_t\lambda_{t+1}(1+\pi_{t+1})^{-1} \tag{A.6}$$

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1}\frac{F_{1,t}}{F_{2,t}} \tag{A.7}$$

$$F_{1,t} = \upsilon_t \xi_t \left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w(1+\chi)} N_t^{1+\chi} + \beta\theta_w E_t\left(\frac{w_t^{\#}}{w_{t+1}^{\#}}\frac{(1+\pi_t)^{\zeta_w}}{1+\pi_{t+1}}\right)^{-\epsilon_w(1+\chi)} F_{1,t+1} \tag{A.8}$$

$$F_{2,t} = \lambda_t(1-\tau_t^N)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w} N_t + \beta\theta_w E_t\left(\frac{w_t^{\#}}{w_{t+1}^{\#}}\right)^{-\epsilon_w}\left(\frac{(1+\pi_t)^{\zeta_w}}{1+\pi_{t+1}}\right)^{1-\epsilon_w} F_{2,t+1} \tag{A.9}$$

$$K_{t+1} = Z_t\left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right]I_t + \left(1 - \delta_0 - \delta_1(u_t - 1) - \frac{\delta_2}{2}(u_t-1)^2\right)K_t \tag{A.10}$$

λ_t is the Lagrange multiplier on the flow budget constraint, (10), and μ_t is the multiplier on the capital accumulation equation, (11). (A.1) defines λ_t in terms of the marginal utility of consumption. Composite consumption, $\widehat{C}_t$, is defined in (A.2). The first order condition for capital utilization is given by (A.3). (A.4) is the optimality condition for the choice of investment, and (A.5) is the optimality condition for the choice of next period's capital stock. The Euler equation for bonds is given by (A.6). (A.7)-(A.8) characterize optimal wage-setting for updating households. The optimal reset wage, $w_t^{\#}$, is common to all updating households. $F_{1,t}$ and $F_{2,t}$ are auxiliary variables. The accumulation equation for physical capital is given by (A.10).

A.2 Firm Optimality Conditions

The optimality conditions for the firm problem described in Subsection 3.1.3 are:

$$w_t = mc_t(1-\alpha)A_t K_{G,t}^{\varphi}\left(\frac{\widehat{K}_t}{N_t}\right)^{\alpha} \tag{A.11}$$

$$R_t = mc_t \alpha A_t K_{G,t}^{\varphi}\left(\frac{\widehat{K}_t}{N_t}\right)^{\alpha-1} \tag{A.12}$$

$$1+\pi_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1}(1+\pi_t)\frac{X_{1,t}}{X_{2,t}} \tag{A.13}$$

$$X_{1,t} = \lambda_t mc_t Y_t + \theta_p \beta E_t (1+\pi_t)^{-\zeta_p \epsilon_p}(1+\pi_{t+1})^{\epsilon_p} X_{1,t+1} \tag{A.14}$$

$$X_{2,t} = \lambda_t Y_t + \theta_p \beta E_t (1+\pi_t)^{\zeta_p(1-\epsilon_p)}(1+\pi_{t+1})^{\epsilon_p - 1} X_{2,t+1} \tag{A.15}$$

Real marginal cost is denoted by mc_t. It is common across all firms, as is the ratio of capital services to labor. (A.11) implies defines a demand curve for labor and (A.12) implicitly defines a demand curve for capital services. Optimal pricing for updating firms is described in (A.13)-(A.15). $1+\pi_t^{\#} = \frac{P_t^{\#}}{P_{t-1}}$ is reset price inflation. $X_{1,t}$ and $X_{2,t}$ are auxiliary variables.

A.3 Government

The equations below describe the behavior of both the fiscal and monetary authorities in the model:

$$G_t + G_{I,t} + i_{t-1}(1+\pi_t)^{-1}b_{g,t} \leq \tau_t^C C_t + \tau_t^N w_t N_t + \tau_t^K R_t \widehat{K}_t + T_t + b_{g,t+1} - b_{g,t}(1+\pi_t)^{-1} \tag{A.16}$$

$$K_{G,t+1} = G_{I,t} + (1-\delta_G)K_{G,t} \tag{A.17}$$

$$\ln G_t = (1-\rho_G)\ln G + \rho_G \ln G_{t-1} + s_G\varepsilon_{G,t} \tag{A.18}$$

$$\ln G_{I,t} = (1-\rho_{G_I})\ln G_I + \rho_{G_I}\ln G_{I,t-1} + s_{G_I}\varepsilon_{G_I,t} \tag{A.19}$$

$$\tau_t^C = (1-\rho_C)\tau^C + \rho_C\tau_{t-1}^C + (1-\rho_C)\gamma_C\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{A.20}$$

$$\tau_t^N = (1-\rho_N)\tau^N + \rho_N\tau_{t-1}^N + (1-\rho_N)\gamma_N\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{A.21}$$

$$\tau_t^K = (1-\rho_K)\tau^K + \rho_K\tau_{t-1}^K + (1-\rho_K)\gamma_K\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{A.22}$$

$$T_t = (1-\rho_T)T + \rho_T T_{t-1} + (1-\rho_T)\gamma_T\left(\frac{B_{G,t}}{Y_t} - \frac{B_G}{Y}\right) \tag{A.23}$$

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\left[\phi_\pi\pi_t + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_i\varepsilon_{i,t} \tag{A.24}$$

(A.16) is the government's flow budget constraint. Government capital accumulates according to (A.17). (A.18)-(A.19) describe the exogenous stochastic processes for government consumption and investment. (A.20)-(A.23) are processes for the different tax instruments. Monetary policy is characterized by (A.24).

A.4 Exogenous Processes

Other exogenous processes in the model are given by:

$$\ln A_t = (1-\rho_A)\ln A + \rho_A\ln A_{t-1} + s_A\varepsilon_{A,t} \tag{A.25}$$

$$\ln Z_t = \rho_Z \ln Z_{t-1} + s_Z\varepsilon_{Z,t} \tag{A.26}$$

$$\ln v_t = \rho_v \ln v_{t-1} + s_v\varepsilon_{v,t} \tag{A.27}$$

$$\ln \xi_t = (1-\rho_\xi)\ln \xi + \rho_\xi \ln \xi_{t-1} + s_\xi \varepsilon_{\xi,t} \tag{A.28}$$

A.5 Aggregate Conditions

$$Y_t = C_t + I_t + G_t + G_{I,t} \tag{A.29}$$

$$v_t^p Y_t = A_t K_{G,t}^{\varphi} \widehat{K}_t^{\alpha} N_t^{1-\alpha} - F \tag{A.30}$$

$$v_t^p = (1+\pi_t)^{\epsilon_p}\left[(1-\theta_p)(1+\pi_t^{\#})^{-\epsilon_p} + \theta_p(1+\pi_{t-1})^{-\zeta_p\epsilon_p} v_{t-1}^p\right] \tag{A.31}$$

$$\widehat{K}_t = u_t K_t \tag{A.32}$$

$$(1+\pi_t)^{1-\epsilon_p} = (1-\theta_p)(1+\pi_t^{\#})^{1-\epsilon_p} + \theta_p(1+\pi_{t-1})^{\zeta_p(1-\epsilon_p)} \tag{A.33}$$

$$w_t^{1-\epsilon_w} = (1-\theta_w) w_t^{\#,1-\epsilon_w} + \theta_w\left(\frac{(1+\pi_{t-1})^{\zeta_w}}{1+\pi_t} w_{t-1}\right)^{1-\epsilon_w} \tag{A.34}$$

A.6 Equilibrium

Expressions (A.1) - (A.34) comprise thirty-four equations in thirty-four variables: $\{C_t, I_t, Y_t, G_t, G_{I,t}, K_{G,t}, K_t, u_t, \widehat{K}_t, N_t, B_{G,t}, \tau_t^C, \tau_t^N, \tau_t^K, T_t, \widehat{C}_t, \lambda_t, \mu_t, i_t, \pi_t, \pi_t^{\#}, R_t, w_t, w_t^{\#}, mc_t, X_{1,t}, X_{2,t}, F_{1,t}, F_{2,t}, A_t, Z_t, v_t, \xi_t\}$. The model features six stochastic shocks – $\{\varepsilon_{G,t}, \varepsilon_{G_I,t}, \varepsilon_{A,t}, \varepsilon_{Z,t}, \varepsilon_{v,t}, \varepsilon_{\xi,t}\}$.

B Measuring Welfare in the Medium Scale DSGE Model

We define aggregate welfare in the model of Section 3 as the equally weighted sum of welfare across households. Let $V_t(h)$ be the welfare of household h. Welfare is the presented discounted value of flow utility, which can be written recursively:

$$V_t(h) = v_t\left\{\frac{\nu}{\nu-1}\ln \widehat{C}_t - \xi_t \frac{N_t(h)^{1+\chi}}{1+\chi}\right\} + \beta E_t V_{t+1}(h) \tag{B.1}$$

Aggregate welfare, $\mathbb{W}_t$, is defined as:

$$\mathbb{W}_t = \int_0^1 V_t(h)dh \tag{B.2}$$

Since households are identical along all non-labor market margins, combining (B.1) with (B.2) yields:

$$\mathbb{W}_t = \upsilon_t \frac{\nu}{\nu - 1} \ln \widehat{C}_t - \upsilon_t \xi_t \int_0^1 \frac{N_t(h)^{1+\chi}}{1+\chi} dh + \beta E_t \mathbb{W}_{t+1} \tag{B.3}$$

We can use (2) to write (B.3) as:

$$\mathbb{W}_t = \upsilon_t \frac{\nu}{\nu - 1} \ln \widehat{C}_t - \upsilon_t \xi_t \frac{N_t^{1+\chi}}{1+\chi} \int_0^1 \left(\frac{w_t(h)}{w_t} \right)^{-\epsilon_w (1+\chi)} dh + \beta E_t \mathbb{W}_{t+1} \tag{B.4}$$

Define $v_t^w = \int_0^1 \left(\frac{w_t(h)}{w_t} \right)^{-\epsilon_w (1+\chi)} dh$. Using properties of Calvo (1983) wage-setting, this can be written without reference to h as:

$$v_t^w = (1 - \theta_w) \left(\frac{w_t^{\#}}{w_t} \right)^{-\epsilon_w (1+\chi)} + \theta_w \left(\frac{w_t}{w_{t-1}} \frac{1 + \pi_t}{(1 + \pi_{t-1})^{\zeta_w}} \right)^{\epsilon_w (1+\chi)} v_{t-1}^w \tag{B.5}$$

Hence, aggregate welfare can be written:

$$\mathbb{W}_t = \upsilon_t \frac{\nu}{\nu - 1} \ln \widehat{C}_t - \upsilon_t \xi_t v_t^w \frac{N_t^{1+\chi}}{1+\chi} + \beta E_t \mathbb{W}_{t+1} \tag{B.6}$$

For the construction of the welfare multiplier, we simply include (B.5) and (B.6) as equilibrium conditions in the model.

C Separately Identifying ϕ_G and ν

We experimented with several different specification in which we sought to jointly estimate the parameters ϕ_G and ν. We also considered several different fixed values of ϕ_G, and re-estimated the model (including ν). Our analysis suggests that these parameters cannot be jointly identified. Accordingly, as a baseline we set $\phi_G = 0.8$ as in Bouakez and Rebei (2007). These authors also report that they cannot jointly identify ϕ_G and ν.

In what follows, we provide some intuition for the non-identification of these parameters jointly. For simplicity, assume that there is no internal habit formation (i.e. $b = 0$). In log deviations, the Lagrange multiplier on the flow budget constraint facing a household can be written:

$$\widetilde{\lambda}_t = -\widehat{c}_t - \frac{1}{\nu} c_t \tag{C.1}$$

Here $\widetilde{\lambda}_t$ is the log-deviation of λ_t from steady state, $\widehat{c}_t$ is the log-deviation of $\widehat{C}_t$ from steady state, and c_t is the log-deviation of of C_t from steady state. Defining $\bar{C}_t = \widehat{C}_t^{\frac{\nu}{\nu-1}}$, $\widehat{c}_t$ can be written:

$$\widehat{c}_t = \frac{\nu-1}{\nu}\phi_G\left(\frac{C}{\bar{C}}\right)^{\frac{\nu-1}{\nu}} c_t + \frac{\nu-1}{\nu}(1-\phi_G)\left(\frac{G}{\bar{C}}\right)^{\frac{\nu-1}{\nu}} g_t \tag{C.2}$$

Here g_t denotes the log-deviation of G_t from its steady state, and variables without a time subscript are steady state values. Combining (C.2) with (C.1) yields:

$$\widetilde{\lambda}_t = -\phi_G\left(\frac{C}{\bar{C}}\right)^{\frac{\nu-1}{\nu}} c_t - \frac{\nu-1}{\nu}(1-\phi_G)\left(\frac{G}{\bar{C}}\right)^{\frac{\nu-1}{\nu}} g_t \tag{C.3}$$

In the conventional case of additively separability, $\widetilde{\lambda}_t$ depends only on c_t. In the more general case, $\widetilde{\lambda}_t$ depends on both c_t and g_t. Holding G and $\bar{C}$ fixed, the elasticity of the Lagrange multiplier on the budget constraint with respect to government spending is given by $-\frac{\nu-1}{\nu}(1-\phi_G)$. What is relevant for the equilibrium dynamics of variables like consumption and output is this elasticity, not the individual parameters ν and ϕ_G. Values of $\nu < 1$ imply that increases in government spending raise the marginal utility of wealth. This complementarity is key for private and government consumption to be positively correlated. Once $\nu < 1$, the model can generate a given elasticity of the marginal utility of wealth with respect to government spending with a relatively low value of ν and a relatively high value of ϕ_G, or a relatively large value of ν and a smaller value of ϕ_G. In our different estimations, we find exactly this pattern – fixing ϕ_G at a relatively lower value results in a higher estimated value of ν and vice-versa, but has virtually no effect on unconditional moments are model fit. Given a fixed value of ϕ_G, the parameter ν does seem to be well-identified.

While ϕ_G and ν do not seem to be well-identified (at least in the region where $\nu < 1$), different values of ϕ_G relevant for the size and magnitude of the welfare multiplier. We discuss this in the text in Section 4.4. In particular, the higher is ϕ_G, the smaller (or more negative) is the welfare multiplier for government consumption. This is intuitive – the larger is ϕ_G, the lower the utility weight households place on government consumption.

D Equilibrium Conditions with Rule of Thumb Consumers

This Appendix lists the full set of equilibrium conditions for the version of our model augment to include rule of thumb (ROT) households. This model is described in Section 5.3 of the text. In what follows, we use o subscripts to demarcate variables pertinent to optimizing households and r subscripts for variables chosen by ROT households.

D.1 Optimizing Household Optimality Conditions

The optimality conditions for an optimizing household are identical to the baseline model. They are listed here again for convenience.

$$(1+\tau_t^C)\lambda_{o,t} = \upsilon_t \frac{1}{\widehat{C}_{o,t}} \phi_G (C_{o,t} - bC_{o,t-1})^{-\frac{1}{\nu}} - \beta b E_t \upsilon_{t+1} \frac{1}{\widehat{C}_{o,t+1}} \phi_G (C_{o,t+1} - bC_{o,t})^{-\frac{1}{\nu}} \tag{D.1}$$

$$\widehat{C}_{o,t} = \phi_G \left(C_{o,t} - bC_{o,t-1}\right)^{\frac{\nu-1}{\nu}} + (1-\phi_G) G_t^{\frac{\nu-1}{\nu}} \tag{D.2}$$

$$(1-\tau_t^K)\lambda_{o,t} R_t = \mu_{o,t}\left(\delta_1 + \delta_2(u_{o,t}-1)\right) \tag{D.3}$$

(D.4)

$$\lambda_{o,t} = \mu_{o,t} Z_t \left[1 - \frac{\kappa}{2}\left(\frac{I_{o,t}}{I_{o,t-1}} - 1\right)^2 - \kappa\left(\frac{I_{o,t}}{I_{o,t-1}} - 1\right)\frac{I_{o,t}}{I_{o,t-1}}\right] + \beta E_t \mu_{o,t+1} Z_{t+1} \kappa \left(\frac{I_{o,t+1}}{I_{o,t}} - 1\right)\left(\frac{I_{o,t+1}}{I_{o,t}}\right)^2$$

$$\mu_{o,t} = \beta E_t \lambda_{o,t+1}(1-\tau_{t+1}^K) R_{t+1} u_{o,t+1} + \beta E_t \mu_{o,t+1}\left(1 - \delta_0 - \delta_1(u_{o,t+1}-1) - \frac{\delta_2}{2}(u_{o,t+1}-1)^2\right) \tag{D.5}$$

$$\lambda_{o,t} = \beta(1+i_t) E_t \lambda_{o,t+1}(1+\pi_{t+1})^{-1} \tag{D.6}$$

$$w_{o,t}^{\#} = \frac{\epsilon_w}{\epsilon_w - 1}\frac{F_{1,t}}{F_{2,t}} \tag{D.7}$$

$$F_{1,t} = \upsilon_t \xi_t \left(\frac{w_{o,t}^{\#}}{w_t}\right)^{-\epsilon_w(1+\chi)} N_{o,t}^{1+\chi} + \beta\theta_w E_t \left(\frac{w_{o,t}^{\#}}{w_{o,t+1}^{\#}}\frac{(1+\pi_t)^{\zeta_w}}{1+\pi_{t+1}}\right)^{-\epsilon_w(1+\chi)} F_{1,t+1} \tag{D.8}$$

$$F_{2,t} = \lambda_{o,t}(1-\tau_t^N)\left(\frac{w_{o,t}^{\#}}{w_t}\right)^{-\epsilon_w} N_{o,t} + \beta\theta_w E_t \left(\frac{w_{o,t}^{\#}}{w_{o,t+1}^{\#}}\right)^{-\epsilon_w}\left(\frac{(1+\pi_t)^{\zeta_w}}{1+\pi_{t+1}}\right)^{1-\epsilon_w} F_{2,t+1} \tag{D.9}$$

$$K_{o,t+1} = Z_t \left[1 - \frac{\kappa}{2}\left(\frac{I_{o,t}}{I_{o,t-1}} - 1\right)^2\right] I_{o,t} + \left(1 - \delta_0 - \delta_1(u_{o,t}-1) - \frac{\delta_2}{2}(u_{o,t}-1)^2\right) K_{o,t} \tag{D.10}$$

D.2 Rule of Thumb Household Optimizing Conditions

Optimization for the ROT household is characterized by the following four conditions:

(D.11) $$(1+\tau_t^C)C_{r,t} = (1-\tau_t^N)w_t N_{r,t} - T_{r,t}$$

(D.12) $$v_t \xi_t N_{r,t}^{\chi} = \lambda_{r,t}(1-\tau_t^N)w_t$$

(D.13) $$(1+\tau_t^C)\lambda_{r,t} = v_t \frac{1}{\widehat{C}_{r,t}} \phi_G (C_{r,t} - bC_{r,t-1})^{-\frac{1}{\nu}} - \beta b E_t v_{t+1} \frac{1}{\widehat{C}_{r,t+1}} \phi_G (C_{r,t+1} - bC_{r,t})^{-\frac{1}{\nu}}$$

(D.14) $$\widehat{C}_{r,t} = \phi_G \left(C_{r,t} - bC_{r,t-1}\right)^{\frac{\nu-1}{\nu}} + (1-\phi_G) G_t^{\frac{\nu-1}{\nu}}$$

D.3 Firm Optimality Conditions

Optimality conditions for firms are the same as in our baseline model. The only minor modification necessary is that firms use the stochastic discount factor of optimizing households to discount future profit flows.

(D.15) $$w_t = mc_t(1-\alpha)A_t K_{G,t}^{\varphi} \left(\frac{\widehat{K}_t}{N_t}\right)^{\alpha}$$

(D.16) $$R_t = mc_t \alpha A_t K_{G,t}^{\varphi} \left(\frac{\widehat{K}_t}{N_t}\right)^{\alpha-1}$$

(D.17) $$1+\pi_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1}(1+\pi_t)\frac{X_{1,t}}{X_{2,t}}$$

(D.18) $$X_{1,t} = \lambda_{o,t} mc_t Y_t + \theta_p \beta E_t (1+\pi_t)^{-\zeta_p \epsilon_p} (1+\pi_{t+1})^{\epsilon_p} X_{1,t+1}$$

(D.19) $$X_{2,t} = \lambda_{o,t} Y_t + \theta_p \beta E_t (1+\pi_t)^{\zeta_p(1-\epsilon_p)} (1+\pi_{t+1})^{\epsilon_p - 1} X_{2,t+1}$$

D.4 Government

The law of motion for government capital and exogenous process for government consumption and investment are:

(D.20) $$K_{G,t+1} = G_{I,t} + (1-\delta_G)K_{G,t}$$

$$\ln G_t = (1-\rho_G)\ln G + \rho_G \ln G_{t-1} + s_G \varepsilon_{G,t} \tag{D.21}$$

$$\ln G_{I,t} = (1-\rho_{G_I})\ln G_I + \rho_{G_I} \ln G_{I,t-1} + s_{G_I} \varepsilon_{G_I,t} \tag{D.22}$$

As noted in the text, we assume that the government balances its budget with lump sum taxes each period. This means that $\tau_t^C = \tau_t^K = \tau_t^N$ and that $b_{g,t} = 0$. This significantly simplifies the government's budget constraint, which can be written: $G_t + G_{I,t} = T_t$. We assume that lump sum taxes for each type of household are proportional to the population weights:

$$T_t = T_{o,t} + T_{r,t} \tag{D.23}$$

$$T_{o,t} = (1-\Phi)\left(G_t + G_{I,t}\right) \tag{D.24}$$

$$T_{r,t} = \Phi\left(G_t + G_{I,t}\right) \tag{D.25}$$

Monetary policy is conducted according to the same Taylor rule as in the baseline model:

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\left[\phi_\pi \pi_t + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_i \varepsilon_{i,t} \tag{D.26}$$

D.5 Exogenous Processes

Other exogenous processes in the model are identical to our baseline model. These are given by:

$$\ln A_t = (1-\rho_A)\ln A + \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \tag{D.27}$$

$$\ln Z_t = \rho_Z \ln Z_{t-1} + s_Z \varepsilon_{Z,t} \tag{D.28}$$

$$\ln v_t = \rho_v \ln v_{t-1} + s_v \varepsilon_{v,t} \tag{D.29}$$

$$\ln \xi_t = (1-\rho_\xi)\ln \xi + \rho_\xi \ln \xi_{t-1} + s_\xi \varepsilon_{\xi,t} \tag{D.30}$$

D.6 Aggregate Conditions

The aggregate market-clearing conditions of the model augmented to include a fraction of ROT households are:

$$Y_t = C_t + I_t + G_t + G_{I,t} \tag{D.31}$$

$$v_t^p Y_t = A_t K_{G,t}^{\varphi} \widehat{K}_t^{\alpha} N_t^{1-\alpha} - F \tag{D.32}$$

$$v_t^p = (1+\pi_t)^{\epsilon_p} \left[(1-\theta_p)(1+\pi_t^{\#})^{-\epsilon_p} + \theta_p (1+\pi_{t-1})^{-\zeta_p \epsilon_p} v_{t-1}^p \right] \tag{D.33}$$

$$\widehat{K}_t = (1-\Phi)\widehat{K}_{o,t} \tag{D.34}$$

$$\widehat{K}_{o,t} = u_{o,t} K_{o,t} \tag{D.35}$$

$$I_t = (1-\Phi) I_{o,t} \tag{D.36}$$

$$C_t = (1-\Phi) C_{o,t} + \Phi C_{r,t} \tag{D.37}$$

$$N_t = (1-\Phi) N_{o,t} + \Phi N_{r,t} \tag{D.38}$$

$$(1+\pi_t)^{1-\epsilon_p} = (1-\theta_p)(1+\pi_t^{\#})^{1-\epsilon_p} + \theta_p (1+\pi_{t-1})^{\zeta_p(1-\epsilon_p)} \tag{D.39}$$

$$w_t^{1-\epsilon_w} = (1-\theta_w) w_{o,t}^{\#,1-\epsilon_w} + \theta_w \left(\frac{(1+\pi_{t-1})^{\zeta_w}}{1+\pi_t} w_{t-1} \right)^{1-\epsilon_w} \tag{D.40}$$

D.7 Equilibrium

Expressions (D.1) - (D.40) comprise forty equations in forty variables: $\{C_{o,t}, I_{o,t}, \widehat{C}_{o,t}, \lambda_{o,t}, \mu_{o,t}, u_{o,t}, K_{o,t}, \widehat{K}_{o,t}, w_{o,t}^{\#}, N_{o,t}, F_{1,t}, F_{2,t}, C_{r,t}, N_{r,t}, \lambda_{r,t}, \widehat{C}_{r,t}, mc_t, w_t, R_t, i_t, \pi_t, \pi_t^{\#}, X_{1,t}, X_{2,t}, \widehat{K}_t, N_t$ $Y_t, G_t, G_{I,t}, K_{G,t}, T_t, T_{o,t}, T_{r,t}, I_t, C_t, v_t^p, A_t, Z_t, v_t, \xi_t\}$.