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The fiscal multiplier

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Abstract

We measure the size of the fiscal multiplier using a heterogeneous agents model with incomplete markets, capital and rigid prices and wages. This environment captures all elements that are considered essential for a quantitative analysis. First, output is (partially) demand determined due to pricing frictions in product and labor markets, so that a fiscal stimulus increases aggregate demand. Second, incomplete markets deliver a realistic distribution of the marginal propensity to consume across the population, whereas all households counterfactually behave according to the permanent income hypothesis if markets are complete. Here, poor households feature high MPCs and thus tend to spend a large fraction of the additional income that arises as a result of a fiscal stimulus, assigning a quantitatively important role to the standard textbook Keynesian cross logic. Interestingly, and unlike conventional wisdom would suggest, our dynamic forward looking model reinforces this channel significantly. Third, the model features a realistic wealth to income ratio since we allow two assets, government bonds and capital. We find that market incompleteness plays the key role in determining the size of the fiscal multiplier, which is about 1.5 if deficit financed and about 0.6 if tax financed. Surprisingly, the size of fiscal multiplier remains similar in the Great recession where the economy was in a liquidity trap. Finally, we elucidate the differences between our heterogeneous-agent incomplete-markets model to those featuring complete markets or hand-to-mouth consumers.

Keywords: Fiscal Multiplier, Incomplete Markets, Sticky Prices, Liquidity Trap

Jel codes: E62, E63, E21, E31

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1 Introduction

In an attempt to stabilize the economy during the Great Recession monetary authorities lowered nominal interest rates to nearly zero and fixed them at that level for a long time. Having reached the limit of traditional monetary policy, U.S. legislators stepped in with the largest fiscal stimulus since the 1930s. Almost a trillion dollars was to be spent by the government, much of it early on, but also with significant spending budgeted to future years up to 2019.

Although attempts to stabilize the economy through fiscal spending occur in virtually every recession, the questions of how much and through which channels an increase in government spending affects output, employment and investment are classic, but the answers are far from being settled. The traditional logic describing the effects of these policies is well known. A government spending stimulus increases aggregate demand which leads to higher labor demand and thus more employment and higher wages. Higher labor income then stimulates consumption, in particular of poor households, which leads to even higher aggregate demand, and thus higher employment, higher labor income, more consumption and so on. The equilibrium impact of an initial government spending of \$1 on output - the fiscal multiplier - is then the sum of the initial increase in government spending and the induced private consumption response.

This simple argument is based on two essential elements which ensure that the stimulus has a *direct* impact on output and employment as well as an *indirect* multiplier effect on private consumption. The first element is that output is demand determined, which ensures that the increase in government spending stimulates aggregate demand. The key underlying assumption is that prices are rigid so that firms adjust quantities and not only prices as a response to more government demand. Firms increase production to satisfy this demand by raising employment and wages, which leads to higher household income. We name this demand and associated output stimulus through an increase in government spending the direct effect. The direct effect differs from the full equilibrium effect in that it keeps prices and taxes unchanged, and, most importantly, does not take into account indirect multiplier effects which arise from higher private consumption. The second element is a significant deviation from the permanent income hypothesis, such that households have a high marginal propensity to consume (MPC) out of the transitory increase in income induced by the stimulus, generating a nontrivial indirect effect. Higher private consumption due to the direct effect then leads to more labor demand, higher labor income and again more consumption and so on.

While this simple argument may be appealing, a quantitative assessment of a stimulus policy requires both elements to be disciplined by the empirical behavior of households and firms to determine if either the direct or indirect effects are significant. This requires a model that, first, features the right amount of nominal rigidities, so that the aggregate demand channel is as in the data. And, second, it requires incorporating observed marginal propensities to consume which imply a substantial deviation from the permanent income hypothesis.

In this paper we measure the size of the fiscal multiplier in a dynamic equilibrium model featuring these two elements disciplined by micro behavior. Specifically, we extend the standard Bewley-Imrohoroglu-Huggett-Aiyagari model to include New-Keynesian style nominal price and wage rigidities. Introducing incomplete markets allows the model to match the rich joint distribution of income, earnings and wealth. Such heterogeneity is crucial in generating a realistic distribution of MPCs and, more generally, for assessing the effects of policies that induce redistribution. The nominal rigidities allow for the model to have a meaningful demand channel operating.

Clearly, "the fiscal multiplier" is not a single number – its size crucially depends on how it is financed (debt, distortionary taxation, reduction of transfers), how persistent fiscal policy is, what households and firms expect about future policy changes, and whether spending is increased or transfers are directed to low-income households. These important details can be incorporated in the model but are difficult to control for in empirical studies. Perhaps it is due to these difficulties that, despite the importance of this research question, no consensus on the size of the multiplier has been reached and findings come with substantial uncertainty (see Ramey (2011) for a survey).[1] Of course, we are not the first to attempt to sidestep these difficulties faced in empirical work by relying on a more theoretical approach. Instead, our contribution is to assess the fiscal multiplier using a model that simultaneously features a

[1]Most of the empirical studies use aggregate data to measure the strength of the fiscal multiplier, which range from around 0.6 to 1.8, although "reasonable people can argue, however, that the data do not reject 0.5 or 2.0" (see Ramey (2011)). Another more recent strand of the literature looks at cross-state evidence and typically finds larger multipliers. However, as Ramey (2011) and Farhi and Werning (2013) have pointed out, the size of the local multipliers found in those studies may not be very informative about the magnitude of aggregate multipliers. For example, the local multiplier could be 1.5 whereas the aggregate multiplier is 0.

demand channel and a realistic consumption response to changes in income.[2]

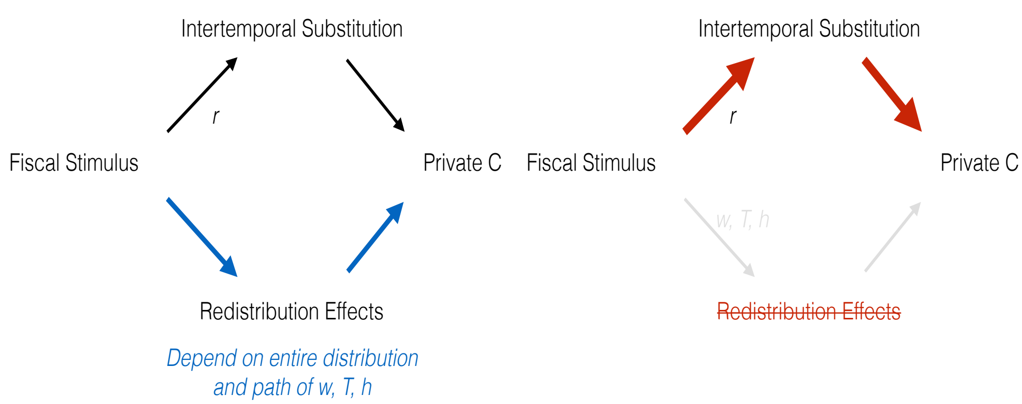
One strand of the existing literature assumes flexible prices and thus eliminates the demand channel. An early example is Baxter and King (1993) who used a representative agent model. Later contributions with heterogeneous agents and incomplete markets include Heathcote (2005) and Brinca et al. (2016). This framework is limited in its ability to provide a full assessment as only the supply but not the demand channel is operative, that is the first essential element is not present.

Another strand of the literature uses New Keynesian models with sticky prices and wages to compute the fiscal multiplier. Nominal rigidities provide a role for the demand channel but now the second essential element is missing because in existing models used for the analysis of fiscal stimulus households are assumed to be representative agents. Such households behave exactly like permanent-income ones and there is no heterogeneity in the marginal propensity to consume. Further, the MPC in response to a temporary shock is small, which stands in the face of the findings of a large empirical literature that has documented substantial MPC heterogeneity and large consumption responses to transitory income and transfer payments. More generally, the consumption block embedded in the Representative Agent New Keynesian (RANK) model focuses on intertemporal substitution of consumption only, whereas the data assign only a small role to such considerations (Kaplan and Violante (2014), Kaplan et al. (2016)).

In our model the fiscal multiplier operates through two channel — intertemporal substitution and redistribution — with interesting interactions. The intertemporal substitution channel describes how government spending changes real interest rates and how this changes private consumption. The strength of this channels depends first on the magnitude of the response of real interest rates and second on how this change in real interest rates affects private consumption. The distributional channel describes the redistributional consequences changes in prices, income, taxes etc. induced by government spending. The strength of this channel depends on the magnitude of the changes in response to spending, and on how that redistribu-

[2]There is a growing literature which incorporates nominal rigidities into incomplete markets models, for example Oh and Reis (2012), Guerrieri and Lorenzoni (2015), Gornemann et al. (2012), Kaplan et al. (2016), Auclert (2016) and Lütticke (2015), McKay and Reis (2016), McKay et al. (2015), Bayer et al. (2015), Ravn and Sterk (2013) and Den Haan et al. (2015), but we are not aware of any contribution in this literature which considers fiscal multipliers.

tion affect private consumption. Here it is important that the response of labor earnings is in line with the data for at least two reasons. First, for asset poor workers income moves basically one-to-one with earnings. Second, the profits of firms move roughly inversely with wages in response to a demand stimulus. Introducing wage rigidities to match the empirical properties of wages bounds the volatility of profits in the model, which is crucial for policy evaluation as the distributional effects arising from the distribution of profits have first order implications. That is why we extend previous work on HANK-type models (that feature incomplete markets and price rigidities, but flexible wages), and allow wages to be as rigid as observed in the data. In addition, these two channels do not operate independently of each other in general equilibrium, but may reinforce or attenuate each other as changes in real interest rate have distributional effects, and redistribution itself affects the equilibrium real interest rate. Panel a) of Figure 1 illustrates the two channels in incomplete markets. In contrast Panel b) of Figure 1 shows the mechanism in complete markets. In this special but standard case only the intertemporal channel is operative.



(a) Incomplete Markets (b) Complete Markets

Figure 1: Channels of Fiscal Stimulus

Our paper is the first to quantify the size of those channels in a model where both are present in a meaningful way and compare our results to the standard model with complete markets. On the one hand, theoretical arguments[3] show that the response of real interest

[3]Indeed, the theoretical findings in Hagedorn (2016) imply that the response of inflation and real interest rates to changes in government spending are smaller in incomplete markets than in complete market models. This is a consequence of the result that incomplete markets combined with fiscal policy specified partially in nominal terms delivers a globally determined price level independently of how monetary policy is specified.

rates is weaker in incomplete markets models than in complete market models, suggesting that the multiplier is smaller here. And Kaplan et al. (2016) show that a given change in real interest rate has smaller effects in incomplete market models than in complete market models. Both arguments together - a smaller response and and a smaller effect of real interest rates - imply that the intertemporal channel is weaker here than if markets were complete. On the other hand, the redistributional channel is larger in incomplete market models (as it is absent in complete markets), suggesting that the multiplier is larger here than in complete market models.

We find that the impact multiplier of an increase in government spending is equal to 0.6 if spending is tax financed and 1.5 if it is deficit financed outside. We then apply our model to assess the size of the fiscal multiplier in a liquidity trap, a question that has received renewed interest in the aftermath of the Great Recession. We threfore engineer a liquidity trap where the natural real interest rate falls below zero and is consistent with salient aggregate dynamics during the Great Recession. The results from the benchmark analysis are relatively little changed. The impact multiplier is now about 0.7 for tax financed and 1.5 for deficit financed spending. Two stark differences to the complete market case require an explanation: the size if the multiplier depends on how it is financed, and the multiplier is quite independent from the state of the economy. The dependence on the type of financing and specifically deficit spending being more effective in stimulating the economy than tax financing is not surprising in models where Ricardian equivalence is violated. Increasing spending and taxes at the same time first stimulates demand but then offsets it through raising taxes which also affects high MPC households. In contrast with deficit financing, the newly issued debt is largely bought by low MPC households whereas high MPC households largely consume additional income. Deficit financing thus implicitly redistributes from asset-rich households with low MPC who finance their consumption more from asset income to low-asset households with high MPC who rely more on labor income so that the aggregate MPC increases.

The reason why we do not find big differences in and outside of a liquidity trap is that the response of the real interest rate in our model is very similar in both scenarios whereas the

In a liquidity trap a large drop in prices on impact is ruled out as this would lead to a large increase in the real value of government debt, which requires an increase in real interest rates (=further drop in prices) for households to be willing to absorb the debt, and so on such that the real value of debt converges to infinity, violating households transversality condition.

response is much larger in a liquidity trap if markets are complete. As a result the magnitude of the intertemporal channel is quite similar across scenarios in our model whereas it is much larger in than outside a liquidity trap if markets are complete. Our preferred decomposition of the strength of the two channels shows that the intertemporal channel contributes 0.95(0.95) and the redistributional channel contributes 0.55(−0.35) to the multiplier of 1.5(0.6) if deficit (tax) financed with a similar decomposition in a liquidity trap. We also find that the multiplier in a liquidity trap gets smaller if prices become more flexible in contrast to the typical findings in the New Keynesian literature. Our results also indicate some limits to scaling up the stimulus since the multiplier is decreasing in the size of the spending stimulus.

The multiplier is high on impact but dies out quite quickly so that the cumulative multiplier, which is the discounted average multiplier over time, falls to 0.5 if spending is tax financed and 1.2 if it is deficit financed. Considering the effect of a pre-announced anticipated spending increase, we find this “forward-spending” to be less effective than an unexpected stimulus. For example, the cumulative multiplier for spending pre-announced four quarters in advance is 0.45 if it is tax financed and 1.3 if it is deficit financed. The main reason being that firms raise prices immediately in anticipation of future higher demand which leads to output losses before the actual policy is implemented.

The benchmark analysis isolates the effects of fiscal policy by assuming a nominal interest fixed at zero. However, we corroborate our benchmark findings when we deviate from this assumption and assume that monetary policy is described by an interest rate feedback rule instead. This happens because prices do not move much. Firms anticipate correctly that the long-run price level returns eventually to its pre-stimulus level which dampens the incentives to increase prices. Together with strong price rigidities, this makes prices move only little so that the interest rate feedback rule implies little movement in interest rates as well.

Incomplete markets models also allows us to conduct a meaningful analysis of transfer multipliers, which is an important objective as many stimulus policies take the form of transfers and not an increase in spending. We also use the theoretical model to compute the welfare consequences of temporary increases in government spending and in transfer payments. This exercise is more interesting than in a complete markets environment since the welfare gains of high MPC households may outweigh the losses of low MPC (rich) households.

Finally, we compare our findings to those of a Two-Agent New Keynesian (TANK) model where one fraction of households is hand-to-mouth and the other fraction behaves according to the permanent income hypothesis delivers a much smaller multiplier even for the same MPC - relating current income to current consumption - as in our HANK model. The reason for this stark difference is the different consumption response both to current and future income increases in both models. Hand-to-mouth consumers spend the full increase in current income but do not respond to increases in future income. In contrast the consumption response is less extreme in our model. Households respond to both current and future income changes, albeit the latter response is smaller. As a result the logic underlying the size of the multiplier is dynamic. An increase in fiscal spending leads to higher income which leads to higher private consumption demand not only today but also in all future periods. This higher path of private spending leads to a higher income path which again increases spending in all periods. In particular we find that today's consumption responds mainly because future income increases and not because of an increase in current income. Indeed the increase in private consumption due to the increase in current income is similar to the small consumption increase in the TANK model which is not surprising since both models feature the same impact MPC.

The paper is organized as follows. Section 2 presents our incomplete markets model with price and wage rigidities. In Section 3 we study the size of the government-spending multiplier both for an interest rate peg and when monetary policy is described by a Taylor rule.

2 Model

The model is a standard New Keynesian model with one important modification: Markets are incomplete as in Aiyagari (1994, 1995) whereas they are complete in a standard New Keynesian model. We add the standard features of new Keynesian models to an incomplete markets model. Price setting faces some constraints as price adjustments are costly as in Rotemberg (1982) leading to price rigidities. As is standard in the New Keynesian literature, final output is produced in several intermediate steps. Final good producers combine the intermediate goods to produce a competitive goods market. Intermediate goods producers are monopolistically competitive. They set a price they charge to the final good producer to maximize profits taking into account the price adjustment costs they face. The intermediate goods producer buy the input, labor, in competitive markets. We also allow for sticky wages and assume that differentiated labor is monopolistically supplied as well.

2.1 Households

The economy consists of a continuum of agents normalized to measure 1 with CRRA preferences over consumption and additively separable preferences for leisure:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t)$$

where:

$$u(c,h) = \begin{cases} \frac{c^{1-\sigma}-1}{1-\sigma} - g(h) & \text{if } \sigma \neq 1 \\ \log(c) - g(h) & \text{if } \sigma = 1, \end{cases}$$

where $\beta \in (0,1)$ is the discount factor and $g(h)$ is the disutility of labor. Agents' labor productivity $\{s_t\}_{t=0}^{\infty}$ is stochastic and is characterized by an N-state Markov chain that can take on values $s_t \in \mathcal{S} = \{s_1, \cdots, s_N\}$ with transition probability characterized by $p(s'|s)$ and $\int s = 1$. Agents rent their labor services, hs, to firms for a real wage w_t and their nominal assets a to the capital market for a nominal rent i^a and a real return $(1+r^a) = \frac{1+i^a}{1+\pi}$, where $1+\pi = \frac{P'}{P}$ is the inflation rate. The nominal return on bonds is i with a real return $(1+r) = \frac{1+i}{1+\pi}$. There are two classes of assets, bonds and capital with potentially different returns, but households can invest in one asset A, which the mutual fund (described below) collects and allocates to bonds and capital.

To allow for sticky wages we follow the literature and assume that each household j provides differentiated labor services, h_{jt}. These differentiated labor services are transformed by a representative, competitive labor packer firm into an aggregate effective labor input, H_t using the following technologies:

$$H_t = \left(\int_0^1 s_{jt} (h_{jt})^{\frac{\epsilon_w - 1}{\epsilon_w}} dj \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{1}$$

where ϵ_w is the elasticity of substitution across labor services.

A middleman firm (e.g. a union) sells households labor services to the labor packer, which given aggregate labor demand H by the intermediate goods sector, minimizes costs

$$\int_0^1 W_{jt} s_{jt} h_{jt} dj, \tag{2}$$

implying a demand for the labor services of household j:

$$h_{jt} = h(W_{jt}; W_t, H_t) = \left(\frac{W_{jt}}{W_t}\right)^{-\epsilon_w} H_t, \tag{3}$$

where W_t is the (equilibrium) nominal wage which can be expressed as

$$W_t = \left(\int_0^1 s_{jt} W_{jt}^{1-\epsilon_w} dj\right)^{\frac{1}{1-\epsilon_w}}.$$

The middleman sets a nominal wage $\hat{W}_t$ for an effective unit of labor so that $W_{jt} = \hat{W}_t$ to maximize profits subject to wage adjustment costs similar to the price adjustment costs as in Rotemberg (1982). These adjustment costs are proportional to idiosyncratic productivity s and are measured in units of aggregate output and are given by a quadratic function of the change in wages above and beyond steady state wage inflation $\overline{\Pi}^w$,

$$\Theta\left(s_{jt}, W_{jt} = \hat{W}_t, W_{jt-1} = \hat{W}_{t-1}; Y_t\right) = s_{jt}\frac{\theta_w}{2}\left(\frac{W_{jt}}{W_{jt-1}} - \overline{\Pi}^w\right)^2 H_t = s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t.$$

The middleman's wage setting problem is to maximize[4]

$$\begin{aligned} V_t^w\left(\hat{W}_{t-1}\right) \equiv & \max_{\hat{W}_t} \int \left(\frac{s_{jt}(1-\tau_t)\hat{W}_t}{P_t} h(\hat{W}_t; W_t, H_t) - \frac{g(h(\hat{W}_t; W_t, H_t))}{u'(C_t)} dj \right. \\ & - \int s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t dj + \frac{1}{1+r_t} V_{t+1}^w\left(\hat{W}_t\right), \end{aligned} \tag{4}$$

where C_t is aggregate consumption. Some algebra (delegated to the appendix) yields, using $h_{jt} = H_t$ and $\hat{W}_t = W_t$ and defining the real wage $w_t = \frac{W_t}{P_t}$, the wage inflation equation

$$\theta_w\left(\pi_t^w - \overline{\Pi^w}\right)\pi_t^w = (1-\tau_t)(1-\epsilon_w)w_t + \epsilon_w \frac{g'(h(\hat{W}_t; W_t, H_t))}{u'(C_t)} + \frac{1}{1+r_t}\theta_w\left(\pi_{t+1}^w - \overline{\Pi^w}\right)\pi_{t+1}^w \frac{H_{t+1}}{H_t}. \tag{5}$$

[4]Equivalently one can think of a continuum of middlemen each setting the wage for a representative part of the population with $\int s = 1$ at all times.

The wage adjustment process does not involve actual costs but is as-if those costs were actually present. We make this assumption to avoid significant movements of these adjustment costs in response to a fiscal stimulus or in a liquidity trap. Such swings would matter in our incomplete markets model and might yield quite different implications from price setting à la Calvo.

Thus, at time t an agent faces the following budget constraint:

$$P_t c_t + a_{t+1} = (1 + i_t^a)a_t + (1 - \tau_t)P_t w_t h_t s_t + T_t$$

where τ_t is a proportional labor tax and T_t is a nominal lump sum transfer. Agents are price takers. In addition households take wages and hours h from the middleman's wage setting problem as given. Thus, we can rewrite the agent's problem recursively as follows:

$$V(a, s; \Omega) = \max_{c\geq 0, a'\geq 0} u(c, l) + \beta \sum_{s\in \mathcal{S}} p(s'|s)V(a', s'; \Omega') \tag{6}$$

$$\text{subj. to} \quad Pc + a' = (1 + i^a)a + P(1 - \tau)whs + T$$

$$\Omega' = \Gamma(\Omega)$$

where $\Omega(a, s) \in \mathcal{M}$ is the distribution on the space $X = A \times S$, agents asset holdings $a \in A$ and labor endowment $s \in S$, across the population, which will together with the policy variables determine the equilibrium prices. $\mathcal{H}$ is an equilibrium object that specifies the evolution of the wealth distribution.

2.2 Production

Final Good Producer A competitive representative final goods producer aggregates a continuum of intermediate goods indexed by $j \in [0, 1]$ and with prices p_j:

$$Y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}.$$

where ϵ is the elasticity of substitution across goods. Given a level of aggregate demand Y, cost minimization for the final goods producer implies that the demand for the intermediate good j is given by

$$y_{jt} = y(p_{jt}; P_t, Y_t) = \left(\frac{p_{jt}}{P_t} \right)^{-\epsilon} Y_t, \tag{7}$$

where P is the (equilibrium) price of the final good and can be expressed as

$$P_t = \left(\int_0^1 p_{jt}^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}.$$

2.2.1 Intermediate-Goods Firms

A monopolist produces intermediate good $j \in [0, 1]$ using the following technology:

$$Y_{jt} = \begin{cases} Z_t K_{jt}^{\alpha} H_{jt}^{1-\alpha} - Z_t F & \text{if} \geq 0 \\ 0 & \text{otherwise} \end{cases}, \tag{8}$$

where $0 < \alpha < 1$, K_{jt} is capital services rented, H_{jt} is labor services rented and the fixed cost of production are denoted $F > 0$.

Intermediate firms rent capital and labor in perfectly competitive factor markets. Profits are fully taxed by the government. A firm's real marginal cost is $mc_{jt} = \partial S_t(Y_{jt})/\partial Y_{jt}$, where

$$S_t(Y_{jt}) = \min_{K_{jt}, H_{jt}} r_t^k K_{jt} + w_t H_{jt}, \text{ where } Y_{jt} \text{ is given by (8)} \tag{9}$$

Given our functional forms, we have

$$mc_t = \left(\frac{1}{\alpha} \right)^{\alpha} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \frac{(r_t^k)^{\alpha} (w_t)^{1-\alpha}}{Z_t} \tag{10}$$

and

$$\frac{K_{jt}}{H_{jt}} = \frac{\alpha w_t}{(1-\alpha) r_t^k} \tag{11}$$

Prices are sticky as there are the same Rotemberg (1982) price adjustment costs as in the simple model.

Given last period's individual price p_{jt-1} and the aggregate state $(P_t, Y_t, Z_t, w_t, r_t)$, the firm chooses this period's price p_{jt} to maximize the present discounted value of future profits, satisfying all demand. The firm's pricing problem is

$$V_t (p_{jt-1}) \equiv \max_{p_{jt}} \frac{p_{jt}}{P_t} y (p_{jt}; P_t, Y_t) - S(y(p_{jt}; P_t, Y_t)) - \frac{\theta}{2} \left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi} \right)^2 Y_t - Z_t \Phi + \frac{1}{1+r_t} V_{t+1} (p_{jt}),$$

where Φ are fixed operating costs.

The same algebra as in the appendix for the case with labor as the only input into production yields the New Keynesian Phillips Curve

$$(1-\epsilon)+\epsilon mc_t-\theta\left(\pi_t-\overline{\Pi}\right)\pi_t+\frac{1}{1+r_t}\theta\left(\pi_{t+1}-\overline{\Pi}\right)\pi_{t+1}\frac{Y_{t+1}}{Y_t}=0$$

The equilibrium real profit of each intermediate goods firm is then

$$d_t=Y_t-Z_tF-S(Y_t).$$

2.2.2 Mutual Fund

The mutual fund collects households savings A_{t+1}/P_{t+1} and pays a real return $\tilde{r}^a_t$ and invest them in real bonds B_{t+1}/P_{t+1} and capital K_{t+1}. It maximizes

$$\Phi(K_{t+2},K_{t+1})+(1+r^k_{t+1}-\delta)(K_{t+1})+(1+r_{t+1})B_{t+1}/P_{t+1}-(1+\tilde{r}^a_{t+1})(A_{t+1}/P_{t+1}),$$

sucht that $A_{t+1}/P_{t+1}=K_{t+1}+B_{t+1}/P_{t+1}+\Phi(K_{t+1},K_t)$ and for adjustment costs $\Phi(K_{t+1},K_t)$, taking K_t and K_{t+2} as given. In equilibrium

$$\begin{aligned}
&r_{t+1}=\tilde{r}^a_{t+1}\\
&1+r^k_{t+1}-\delta=(1+\tilde{r}^a_{t+1})(1+\Phi_1(K_{t+1},K_t))-\Phi_2(K_{t+2},K_{t+1})\\
&A_{t+1}/P_{t+1}=K_{t+1}+B_{t+1}/P_{t+1}+\Phi(K_{t+1},K_t).
\end{aligned}$$

The same first order conditions would arise in an intertemporal optimization problem where profits are discounted at rate $\tilde{r}^a$. The objective function above shows all parts of the full intertemporal objective function where $t+1$ terms appear, evaluated in period $t+1$.

The total profits of the fund are

$$D^{MF}_{t+1}=(1+r^k_{t+1}-\delta)K_{t+1}+(1+r_{t+1})B_{t+1}/P_{t+1}-(1+\tilde{r}^a_{t+1})(A_{t+1}/P_{t+1}),$$

and per unit of investment are $d^{MF}_{t+1}=D^{MF}_{t+1}/(A_{t+1}/P_{t+1})$. Households therefore receive (or have to pay) $d_{t+1}A_{t+1}/P_{t+1}$ in period $t+1$ per unit invested such that households' return equals

$$(1+r^a_{t+1})=(1+\tilde{r}^a_{t+1}+d^{MF}_{t+1}).$$

2.3 Government

The government obtains revenue from taxing labor income, issuing bonds and taxing profits at 100%. Household labor income wsl is taxed progressively with a nominal lump-sum transfer T_t and a proportional tax τ:

$$\tilde{T}(wsh) = -T + \tau Pwsh.$$

The government issues nominal bonds denoted by B^g, with negative values denoting government asset holdings and fully taxes profits away, obtaining nominal revenue Pd.

The government uses the revenue to finance exogenous nominal government expenditures, G_t, interest payments on bonds and transfers to households.

The government budget constraint is therefore given by:

$$B^g_{t+1} = (1 + i_t)B^g_t + G_t - P_t d_t - \int \tilde{T}_t(w_t s_t h_t) d\Omega. \tag{12}$$

2.4 Equilibrium

Market clearing requires that the labor demanded by the firm is equal to the aggregate labor and that the bonds issued by the government and capital demand equals the amount of assets provided by households:

$$K_{t+1} + B_{t+1}/P_{t+1} + \Phi(K_{t+1}, K_t) = A_{t+1}/P_{t+1} = \int_{a_t} \sum_{s_t \in \mathcal{S}} a_{t+1}(a_t, s_t) d\Omega_t(a_t, s_t) \tag{13}$$

$$H_t = \int n_{jt} dj \tag{14}$$

where we have abused notation slightly here, $a_{t+1}(a_t, s_t)$ is the asset choice of an agent with asset level a_t and period labor endowment s_t.

Definition: A monetary competitive equilibrium is a sequence of prices P_t, tax rates τ_t, nominal transfers T_t, nominal government spending G_t, bonds B^g_t, a value functions $v_t : X \times \mathcal{M} \to \mathcal{R}$ with policy functions $a_t : X \times \mathcal{M} \to \mathcal{R}_+$ and $c_t : X \times \mathcal{M} \to \mathcal{R}_+$, hours $H_t : A \to \mathcal{R}_+$, capital $K_t : A \to \mathcal{R}_+$, pricing functions $r_t : A \to \mathcal{R}$ and $w_t : A \to \mathcal{R}_+$, and a law of motion $\Gamma : A \to A$, such that:

1. v_t satisfies the Bellman equation with corresponding policy functions a_t and c_t given

price sequences $r_t(), w_t()$ and hours H_t.

2. Prices are set optimally by firms.

3. Wages are set optimally by middlemen.

4. The mutual fund maximizes profits taking prices as given.

5. For all $\Omega \in \mathcal{M}$:

$$\begin{aligned} K_{t+1} + B_{t+1}/P_{t+1} + \Phi(K_{t+1}, K_t) &= \int a_{t+1}(a, s; \Omega_t) d\Omega_t / P_{t+1}, \\ H_t(\Omega_T) &= \int n_{jt} dj, \\ Y_t = Z_t K_t^\alpha H_t^{1-\alpha} &= \int c(a, s; \Omega) d\Omega_t + \frac{G}{P} + F + K_{t+1} - (1-\delta) K_t + \Phi(K_{t+1}, K_t). \end{aligned}$$

6. Aggregate law of motion Γ generated by a' and p.

3 The Fiscal Multiplier

In this Section we calculate the fiscal multiplier in our model with incomplete markets, conducting the following experiment. Assume that the economy is in steady state with nominal bonds B_{ss}, government spending G_{ss}, transfers T_{ss} and a tax rate τ_{ss} and where the price level is P_{ss}. The real value of bonds is then B_{ss}/P_{ss}, the real value government expenditure is G_{ss}/P_{ss} and so on. We then consider an M.I.T. (unexpected and never-again-occuring) shock to government expenditures and compute the impulse response to this persistent innovation in G. Eventually the economy will reach the new steady state characterized by government bonds $B_{ss}^{new} = B_{ss}$, government spending $G_{ss}^{new} = G_{ss}$, transfers $T_{ss}^{new} = T_{ss}$ and a tax rate $\tau_{ss}^{new} = \tau_{ss}$ the price level is P_{ss}^{new}.

3.1 The Fiscal Multiplier in Incomplete Market Models

In our model the fiscal multiplier operates through two channel — intertemporal substitution and redistribution — with interesting interactions. The intertemporal substitution channel describes how government spending changes real interest rates and how this changes private consumption. The distributional channel describes how government spending changes prices, income, taxes etc., the redistributional consequences of these changes and the resulting impact on private consumption. We now explain the role of these two channels in determining the fiscal multiplier in our model, what determines their strength and explain the differences to complete markets.

3.1.1 Intertemporal Substitution Channel

To understand the workings of the intertemporal substitution channel in our model it is instructive to start with the complete markets case where this is the only channel operational. We then move to incomplete markets to explain and understand the differences.

The size of the multiplier m is determined by the response of the real interest rates only. The Consumption Euler equation for our utility function, $\frac{C^{1-\sigma}}{1-\sigma} + ...$

$$C_t^{-\sigma} = \beta(1 + r_{t+1})C_{t+1}^{-\sigma}. \tag{15}$$

Iterating this equation and assuming that consumption is back to the steady state level at time T, $C_T = C_{ss}$, we obtain for consumption at time $t = 1$ when spending is increased,

$$C_1^{-\sigma} = \Big(\prod_{t=1}^{T-1} \big(\beta(1 + r_{t+1})\big)C_T^{-\sigma}, \tag{16}$$

so that the initial percentage increase in consumption and thus the fiscal multiplier equals

$$m = \frac{C_1}{C_{ss}} = \Big(\prod_{t=1}^{T-1} \beta(1 + r_{t+1})\Big)^{\frac{-1}{\sigma}} = \Big(\prod_{t=1}^{T-1} \frac{1 + r_{t+1}}{1 + r_{ss}}\Big)^{\frac{-1}{\sigma}} \tag{17}$$

where we have used that $\beta(1 + r_{ss}) = 1$ in a complete markets steady state. As a result the size of the fiscal multiplier is one-to-one related to the accumulated response of real interest rate which is induced by the fiscal stimulus,

$$\log(m) = \underbrace{\frac{1}{\sigma}}_{\text{Intertemporal Substitution}} \sum_{t=1}^{T-1} \underbrace{\left(\log(1 + r_{ss}) - \log(1 + r_{t+1})\right)}_{\text{Change of real interest rates}}, \tag{18}$$

which can be decomposed in the change in the real interest rate, $\approx r_t - r_{ss}$, and the effect of this change on consumption, whose strength is governed by the IES, $\frac{1}{\sigma}$. Both components of the intertemporal substitution channel are weaker in incomplete market models. The effect of the real interest rate on consumption is smaller since some households are credit constrained and thus not on their Euler equation, breaking the tight link between consumption and real interest rates. Also the change in real interest rates is smaller. To understand the difference assume for simplicity that the nominal interest rate is fixed at i_{ss} and that the steady state is reached after T periods such that

$$\prod_{t=1}^{T-1}(1+r_{t+1}) = \prod_{t=1}^{T-1}\left(\frac{1+i_{ss}}{1+\pi_{t+1}}\right) = \prod_{t=1}^{T-1}(1+i_{ss})\frac{P_T}{P_1} = \prod_{t=1}^{T-1}(1+i_{ss})\frac{P_{ss}^{new}}{P_1}, \tag{19}$$

so that the response of $\log(\prod_{t=1}^{T-1}(1+r_{t+1}))$ is one-to-one related to the response of $\log(P_{ss}^{new}) - \log(P_1))$. This response is quite large in complete market models (Christiano et. al. (2011)) but small here. The reason is that P_{ss}^{new} does not respond at all and P_1 falls but not that much.

Both results are a consequence of the result that incomplete markets combined with fiscal policy specified partially in nominal terms delivers a globally determined price level independently of how monetary policy is specified (Hagedorn (2016)). A large drop in P_1 is ruled out as this would lead to a large increase in the real value of government debt, which requires an increase in real interest rates (=further drop in prices) for households to be willing to absorb the debt, and so on such that the real value of debt converges to infinity, violating households transversality condition. The reason why $P_{ss}^{new} = P_{ss}$ is that both prices solve the same asset market clearing condition

$$S(1+r_{ss}, ...) = \frac{B_{ss}}{P_{ss}} = \frac{B_{ss}^{new}}{P_{ss}} = \frac{B_{ss}^{new}}{P_{ss}^{new}}. \tag{20}$$

Together these arguments imply that the intertemporal substitution channel is weaker in our incomplete markets model than in the corresponding complete markets model.

3.1.2 Distributional Consequences of a Stimulus

An increase in spending, the necessary adjustments in taxes and transfers and the resulting responses of prices and hours operate through various distributional channels. Changes in the tax code naturally deliver winners and losers. An increase in the price level and of labor income leads to a redistribution from households who finance their consumption more from asset income to households who rely more on labor income. Changes in interest rates also redistribute between debtors and lenders.

These redistributions matter due to the endogenous heterogeneity in the MPCs in the data and in our incomplete markets model. This heterogeneity together with the redistribution determines the aggregate consumption response, and since output is demand determined due to price rigidities, also determines output. Individual household consumption c_t depends on transfers T, tax rates τ, labor income wh, prices P and nominal interest rates i, so that aggregate private consumption

$$C_t\big(\{T_t, \tau_t, w_t h_t, P_t, i_t\}_{t\geq 0}\big) = \int c_t(a, s; \{T_t, \tau_t, w_t h_t, P_t, i_t\}_{t\geq 0}) d\Omega_t. \tag{21}$$

In our model hours is a household choice variable but demand determined as well. Of course consumption and hours worked are jointly determined in equilibrium but to understand the demand response of the fiscal stimulus it turns out to be useful to consider wh as exogenous for consumption decisions here. In particular it allows us to distinguish between the initial impact,"first round", demand impulse due to the policy change and "second, third ... round" due to equilibrium responses. Those arise in our model since an initial policy-induced demand stimulus leads to more employment by firms, and so higher labor income which in turn implies more consumption demand, which again leads to more employment and so on until an equilibrium is reached where all variables are mutually consistent. Denoting pre stimulus variables by a bar, we can now decompose the aggregate consumption response,

$$(\Delta C)_t = C_t\big(\{T_t, \tau_t, w_t h_t, P_t, i_t\}_{t\geq 0}\big) - C_t\big(\{\bar{T}, \bar{\tau}, \bar{w}\bar{h}, \bar{P}, \bar{i}\}_{t\geq 0}\big) \tag{22}$$

into its different channels:

$$
\begin{aligned}
(\Delta C)_t \quad = \quad & \underbrace{C_t\big(\{T_t, \tau_t, \bar{w}\bar{h}, \bar{P}, \bar{i}\}_{t\geq 0}\big) - C_t\big(\{\bar{T}, \bar{\tau}, \bar{w}\bar{h}, \bar{P}, \bar{i}\}_{t\geq 0}\big)}_{\text{Direct Impact of Transfers and Taxes}} && (23)\\
+ \quad & \underbrace{C_t\big(\{T_t, \tau_t, w_t h_t, \bar{P}, \bar{i}\}_{t\geq 0}\big) - C_t\big(\{T_t, \tau_t, \bar{w}\bar{h}, \bar{P}, \bar{i}\}_{t\geq 0}\big)}_{\text{Indirect Equilibrium Effect: Labor Income}} && (24)\\
+ \quad & \underbrace{C_t\big(\{T_t, \tau_t, w_t h_t, P_t, i_t\}_{t\geq 0}\big) - C_t\big(\{T_t, \tau_t, w_t h_t, \bar{P}, \bar{i}\}_{t\geq 0}\big)}_{\text{Price and Interest rate Adjustment}} && (25)
\end{aligned}
$$

Total demand is the sum of private consumption demand C and real government consumption $g = G/P$, which both determine output. The private consumption response does not directly depend on G/P but it does indirectly. First, transfers T and taxes τ have to adjust to balance the intertemporal government budget constraint. Second, increases in G/P translate one-for-one into increases in demand. On impact an increase by Δg increases demand by Δg and thus our worked from h_{ss} to $h_{ss} + \Delta g$. As before, this increase in labor income stimulates private demand which in turn leads to higher employment, then again higher consumption and so on until convergence. We therefore decompose the total demand effect ΔD of an increase in government spending by Δg as

$$
\begin{aligned}
(\Delta D)_t \quad = \quad & \underbrace{(\Delta g)_t}_{\text{Direct Govt' Spending Response}} + \underbrace{(\Delta C)_t}_{\text{Private Consumption Response}} && (26)\\
= \quad & (\mathbf{\Delta g})_\mathbf{t} + \underbrace{C_t\big(\{\bar{T}, \bar{\tau}, \bar{w}(\bar{h} + \mathbf{\Delta g}), \bar{P}, \bar{i}\}_{t\geq 0}\big) - C_t\big(\{\bar{T}, \bar{\tau}, \bar{w}\bar{h}, \bar{P}, \bar{i}\}_{t\geq 0}\big)}_{\text{Direct Impact on Private Consumption}} && (27)\\
+ \quad & \underbrace{C_t\big(\{T_t, \tau_t, w_t h_t, P_t, i_t\}_{t\geq 0}\big) - C_t\big(\{\bar{T}, \bar{\tau}, \bar{w}(\bar{h} + \mathbf{\Delta g}), \bar{P}, \bar{i}\}_{t\geq 0}\big)}_{\text{Indirect Private Consumption Response}} && (28)
\end{aligned}
$$

A fiscal stimulus, in addition to the immediate impact on government demand, also leads to higher employment and labor income and thus stimulates private consumption, the *Direct Impact on Private Consumption*. The remainder of the private consumption is as above the sum of the direct impact of transfers and taxes, the indirect equilibrium effects of labor income and and price and interest rate adjustment, such that the full decomposition of the total demand effect ΔD is

$$
\begin{aligned}
(\Delta D)_t \quad = \quad & \underbrace{(\Delta g)_t}_{\text{Direct G Impact}} & (29)\\
+ \quad & \underbrace{C_t\big(\{\bar{T},\bar{\tau},\bar{w}(\bar{h}+\Delta g),\bar{P},\bar{i}\}_{t\geq 0}\big) - C_t\big(\{\bar{T},\bar{\tau},\bar{w}\bar{h},\bar{P},\bar{i}\}_{t\geq 0}\big)}_{\text{Direct G Impact on C}} & (30)\\
+ \quad & \underbrace{C_t\big(\{T_t,\tau_t,\bar{w}(\bar{h}+\Delta g),\bar{P},\bar{i}\}_{t\geq 0}\big) - C_t\big(\{\bar{T},\bar{\tau},\bar{w}(\bar{h}+\Delta g),\bar{P},\bar{i}\}_{t\geq 0}\big)}_{\text{Indirect Tax/Transfer Impact}} & (31)\\
+ \quad & \underbrace{C_t\big(\{T_t,\tau_t,w_t h_t,\bar{P},\bar{i}\}_{t\geq 0}\big) - C_t\big(\{T_t,\tau_t,\bar{w}(\bar{h}+\Delta g),\bar{P},\bar{i}\}_{t\geq 0}\big)}_{\text{Indirect Labor Income Impact}} & (32)\\
+ \quad & \underbrace{C_t\big(\{T_t,\tau_t,w_t h_t,P_t,i_t\}_{t\geq 0}\big) - C_t\big(\{T_t,\tau_t,w_t h_t,\bar{P},\bar{i}\}_{t\geq 0}\big)}_{\text{Indirect Price and Interest Impact}} & (33)
\end{aligned}
$$

3.1.3 Multiplier: Definition

As we can now be sure that the fiscal multiplier is well defined in our economy, we now follow Farhi and Werning (2013) in computing the response of the economy to a fiscal stimulus.

Concretely, we compute the response of the economy to an unexpected increase in the path of nominal government spending to $G_0, G_1, G_2, \ldots, G_t, \ldots, G_{ss}$, where G_{ss} is the steady nominal spending level and $G_t \geq G_{ss}$.

We summarize the effects of spending on output in several ways. First, we compute the path of dynamic multipliers as the sequence of

$$m_t^{DYN} = \frac{\frac{Y_t}{Y_{ss}} - 1}{\frac{G_0 P_{ss}}{P_0 G_{ss}} - 1} \frac{Y_{ss}}{G_{ss}/P_{ss}}, \tag{34}$$

and the present value multipliers as

$$m_t^{PV} = \frac{\sum_{k=0}^{t} \beta^k (\frac{Y_k}{Y_{ss}} - 1)}{\sum_{k=0}^{t} \beta^k (\frac{G_k P_{ss}}{P_k G_{ss}} - 1)} \frac{Y_{ss}}{G_{ss}/P_{ss}}, \tag{35}$$

where the two statistics coincide at $t = 0$ and represent the impact multiplier. A useful statistic is then the long-run present value multiplier, which represents the discounted percentage change in real output to the discounted percentage change in real government spending for any path of government spending:

$$\overline{M} = m_\infty^{PV} = \frac{\sum_{t=0}^{\infty}\beta^t(\frac{Y_t}{Y_{ss}}-1)}{\sum_{t=0}^{\infty}\beta^t(\frac{G_tP_{ss}}{P_tG_{ss}}-1)}\frac{Y_{ss}}{G_{ss}/P_{ss}}, \tag{36}$$

where P_{ss}, G_{ss}, Y_{ss} are the steady state price level, nominal spending and real output respectively and $\frac{G_t}{P_t}$ is real government spending. For comparison with the complete markets case we also compute the as-if dynamic complete markets multiplier, m_t^{CM}, using the price path we obtain from our model. Iterating the consumption Euler equation yields the as-if percentage response of aggregate consumption,

$$\frac{C_t}{C_{ss}} - 1 = \prod_{s=t}^{\infty}(1+\pi_{t+1}) - 1 = \frac{P_{ss}^{new}}{P_t} - 1.$$

Since the multiplier is in terms of units of consumption and not in percentages, adjusting for the magnitudes of steady state consumption, output and government spending,

$$\begin{aligned}
m_t^{CM} &= \frac{\frac{C_t-C_{ss}}{C_{ss}}\frac{C_{ss}}{Y_{ss}} + \frac{G_t/P_t - G_{ss}/P_{ss}}{Y_{ss}}}{\frac{G_0P_{ss}}{P_0G_{ss}}-1}\frac{Y_{ss}}{G_{ss}/P_{ss}} \\
&= \frac{\frac{C_t-C_{ss}}{C_{ss}}}{\frac{G_0P_{ss}}{P_0G_{ss}}-1}\frac{C_{ss}}{G_{ss}/P_{ss}} + \frac{G_t/P_t - G_{ss}/P_{ss}}{G_0/P_0 - G_{ss}/P_{ss}} \\
&= \frac{\frac{\mathbf{P_{ss}^{new}}-\mathbf{P_t}}{\mathbf{P_t}}}{\frac{G_0P_{ss}}{P_0G_{ss}}-1}\frac{C_{ss}}{G_{ss}/P_{ss}} + \frac{G_t/P_t - G_{ss}/P_{ss}}{G_0/P_0 - G_{ss}/P_{ss}}
\end{aligned}$$

3.2 Calibration

To quantitatively assess the size of the fiscal multiplier we now calibrate the model.

Preferences Households have separable preferences over labor and constant relative risk aversion preferences for consumption. We set the risk-aversion parameter, σ, equal to 1. Following Krueger et al. (2016), we assume there permanent discount factor heterogeneity across agents. We allow for two values of the discount factor, which we choose to match the Gini of net worth net of home equity in the 2013 SCF and aggregate savings to quarterly GDP of 11.46[5]. We assume the functional form for g:

[5] We calibrate to a capital to quarterly output ratio of 10.26, and government debt to quarterly GDP ratio of 1.2.

$$g(h) = \psi \frac{h^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} \tag{37}$$

We set the Frisch elasticity, $\varphi = 0.5$, following micro estimates. We choose $\psi = 0.6$ such that in steady state $h = 1/3$.

Productivity Process We follow Krueger et al. (2016) who use data from the Panel Survey of Income Dynamics to estimate a stochastic process for labor productivity. They estimate that log income consists of a persistent and transitory component. They estimate that the persistent shock has an annual persistence of 0.9695 and variance of innovations of 0.0384. The transitory shock is estimated to have variance 0.0522. We follow Krueger et al. (2016) in converting these annual estimates into a quarterly process. We discretize the persistent shock into a seven state Markov chain using the Rouwenhorst method and integrate over the transitory shock using Gauss-Hertmite quadrature with three nodes.

Production Technology We set the capital share $\alpha = 0.36$. We choose the quarterly depreciation rate $\delta = 0.032$ to generate a real return on capital net of depreciation of 0 BP when the capital output ratio is 10.26. We asume the function form for Φ:

$$\Phi(K', K) = \frac{\phi_k}{2} \left(\frac{K' - K}{K} \right)^2 K, \tag{38}$$

and set $\phi_k = 17$ to match estimates of the elasticity of investment to Tobin's q from Eberly, Rebelo, and Vincent (2008). We choose the elasticity of substitution between intermediate goods, $\epsilon = 10$, to match an average markup of 10%. The adjustment cost parameter on prices, $\theta = 300$, to match a slope of the NK Philips curve, $\epsilon/\theta = 0.03$. We set the firm operating cost Φ equal to the steady state markup such that steady state profits equal 0 (Basu and Fernald (1997)). These profits are fully taxed and are distributed to households as lump-sum transfers in the benchmark.

Government We set the proportional labor income tax, τ equal to 25%. We set nominal government spending, G in steady state equal to 15% of output. The value of of lump-sum transfers T is set to 8.55% of output such that roughly 40% of households receive a net transfer from the government (Kaplan et al., 2016).

Monetary Policy For the benchmark specification we assume that the monetary authority operates a constant interest rate peg of $i = 0$. Note that the results in Hagedorn (2016) imply that there is a unique response of prices, output, consumption and employment although monetary policy is not following an active rule, a necessary requirement for a locally determined equilibrium. For purposes of comparison, we will also solve for transitions where we assume that the monetary authority follows a Taylor rule, which sets the nominal interest rate according to:

$$i_{t+1} = \max(X_{t+1}, 0) \tag{39}$$

where

$$X_{t+1} = \left(\frac{1}{\zeta}\right)\left(\frac{P_t}{P_{ss}}\right)^{\phi_1(1-\rho_R)}\left(\frac{Y_t}{Y_{ss}}\right)^{\phi_2(1-\rho_R)}[\zeta(1+i_t)]^{\rho_R} - 1.$$

We follow the literature in setting $\rho_R = 0.8$, $\phi_1 = 1.5$, $\phi_2 = 0$ and $\zeta = 1/(1 + r_{ss})$. Fiscal monetary coordination will be carried out under various schemes listed in the next section.

Price and Wage Philips Curves We set the slopes of both the NK price and wages Philips curve to 0.03, which is at the lower end of available estimates.

Parameter Values

Steady State Model Fit Table II shows that we match the distribution of net worth as well as the Gini coefficient quite well.

In the model 2% of agents have 0 wealth, and 14% of agents less than \$1000. The annual MPC out of transitory income equals 0.4, which is in the middle range of empirical estimates 0.2-0.6 (e.g. **?**.) Figure 2 shows the distribution of first period MPCs as function of households assets for transfers of various sizes, 1\$, 1000\$ and 10000\$.

Figure 3 shows the dynamic response of aggregate consumption $\{C_t\}_{t=0,1,2...}$ to transfers of various sizes, 1\$, 1000\$ and 10000\$ paid once at periods $0, 4, 8$ and 12.

Table I: Calibrated Parameters

Parameter	Interpretation	Internally Calibrated	Value
σ	Risk-aversion	N	2
β	Discount Factor	Y	1.3
φ	Frisch Elasticity	N	0.5
ψ	Labor disutility	Y	0.6
ϵ	Elas. substitution	N	10
θ_p	Price adjustment	N	300
θ_w	Wage adjustment	N	300
Φ	Firm Fixed Cost	Y	0.1
τ	Labor tax	N	25%
T	Transfer	Y	7.5% of income
θ_w	Wage adjustment	N	300

Table II: Net Worth Distributions: Data vs Model

% Share held by:	Data (SCF 07)	Model
Q1	-0.2	0.3
Q2	1.2	1.3
Q3	4.6	3.4
Q4	11.9	10.3
Q5	82.5	84.7
90-95	11.1	16.7
95-99	25.3	31.1
Top 1%	33.5	18.5
Gini	0.78	0.79

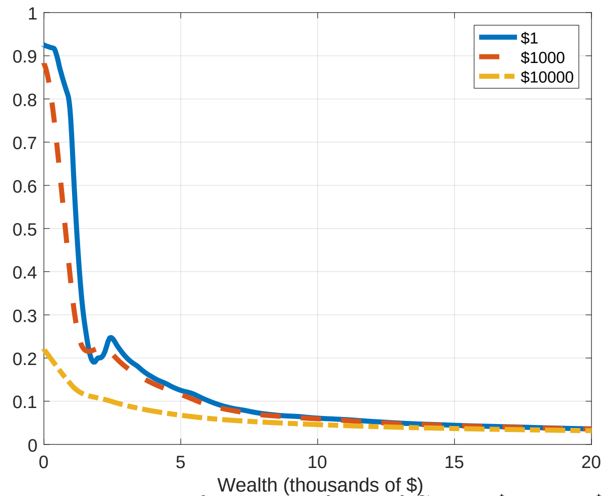


Figure 2: Propensity to consume for Transfers of Size 1$, 1000$ and 10000$.

3.3 Results

We can now compute the response of prices, employment, output and consumption to a persistent increase in nominal government consumption by one percent where spending follows an AR(1) process with parameter $\rho_g = 0.7$ after the initial innovation. Balancing the government budget when government spending is increased requires to adjust taxes or debt or both. As Ricardian equivalence does not hold in our model different assumptions on the path of taxes and debt will have different implications for the path of aggregate consumption and therefore prices and the change in output. We consider two scenarios:

1. Transfer are adjusted period by period to keep nominal debt constant.

2. Deficit financing and delayed transfers to pay back debt after 12 quarters.

For each of the two scenarios we report the dynamic response of hours, consumption, output, prices, tax revenue and debt as well as the of the path of dynamic and static multipliers m_t^D, m_t^S and of the as-if complete markets multiplier m_t^{CM} and the summary multiplier $\overline{M}$.

3.3.1 Tax Financing: Constant nominal debt

Under the first financing scheme, we assume that the government adjusts lump-sum transfers period by period to keep the level of nominal debt constant. The four panels of Figure 5 show the results for the aggregate consumption and output response, the different multipliers, the decomposition of aggregate consumption, and government bonds[6].

[6]Note: the results presented in this section are for the model without physical capital. For the lastest draft see the authors' website.

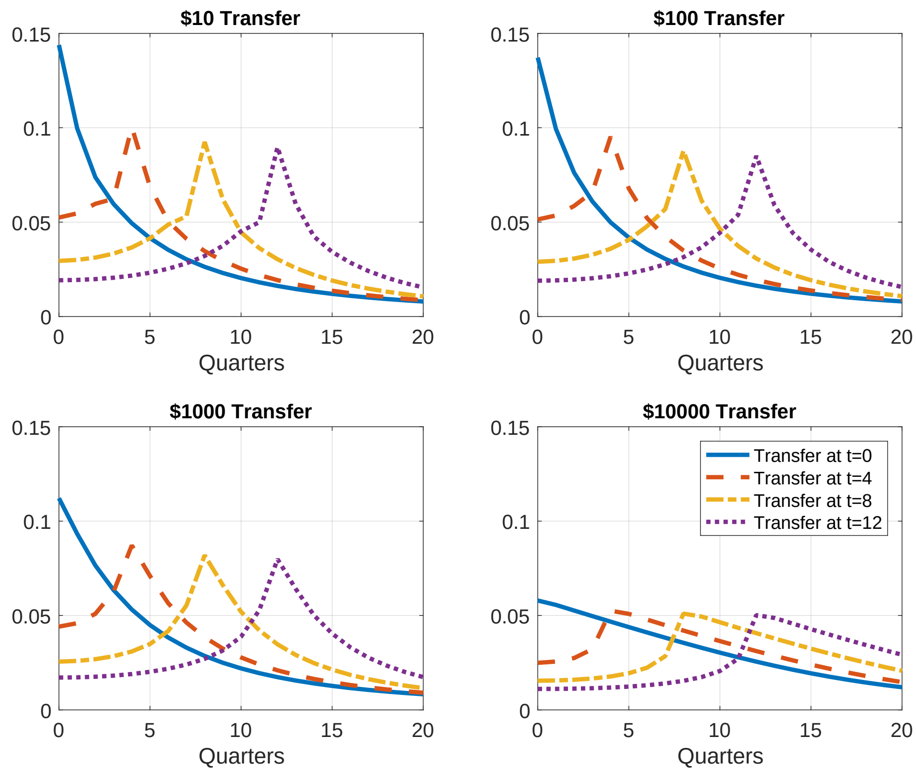


Figure 3: Propensity to consume for Transfers of Size 1$, 100$ 1000$ and 10000$.

The level of government bonds is unchanged since the stimulus is tax-financed. On impact G increases by 1% that is 0.15% of output and consumption decreases by 0.023% of output leading to an impact multiplier of 0.847. The consumption responds weakens over time and gets negative from period 6 onwards The dynamic multiplier converges to zero since the consumption response although negative slowly dies out and becomes small relative to initial government spending increase. The decomposition of the total consumption response reveals the quantitative importance of the direct, the indirect and the price effects. The stimulus of 0.15% directly increases households labor supply by the same amount, leading to a aggregate consumption response of 0.020% of output. (equation 30). The contemporaneous cut in transfers lowers aggregate consumption by 0.038% on impact (equation 31) , implying a total initial negative effect of -0.018%. This effect is negative since the government spending increases households income proportional to their productivity and thus benefits high income households more where the transfer cut is uniformly across all income groups and thus negatively

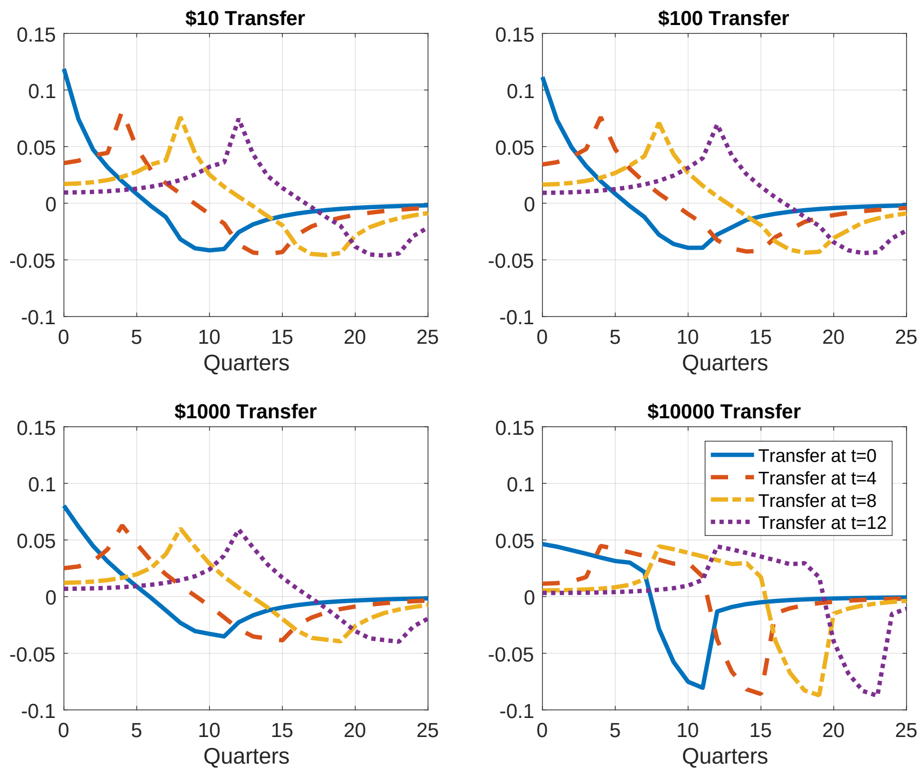


Figure 4: Propensity to consume for Transfers of Size 1\$, 100\$ 1000\$ and 10000\$ that are repaid after two years.

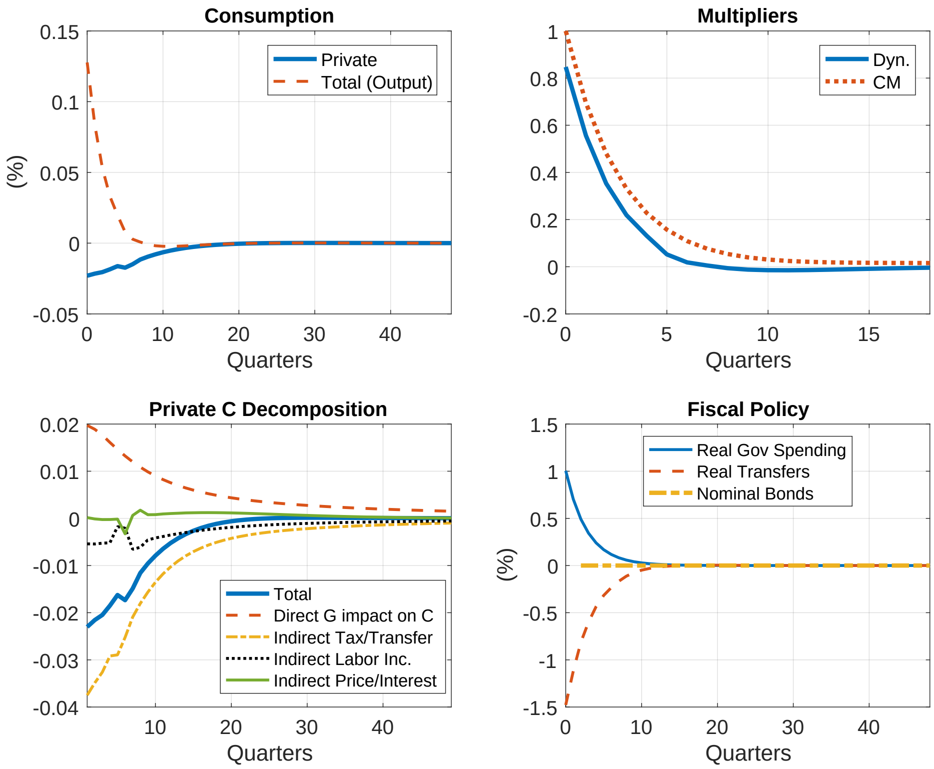
affects high MPH households. This decrease leads to lower consumption demand, which in turn leads to lower labor demand, lower labor income and again lower consumption demand until an equilibrium is reached. These indirect multiplier effects sum up to -0.005% (equation 32) further lowering the consumption response. Finally, the decomposition shows that the price increase (and the unchanged interest rate) effects are small (equation 33).

The impulse response of the remaining variables to a 1% innovation in government spending are plotted in Figure A-1 in the appendix. The cumulated multiplier, reported in Table III, is only 0.63.

3.3.2 Deficit financing

Under this scenario we assume that real transfers are kept constant during the first 20 quarters after the innovation to government spending. Then, the government is assumed to adjust transfers linearly over eight quarters, keep them constant for eight quarters, and then allow

Figure 5: Fiscal Multiplier and Aggregate Consumption: Tax Financing

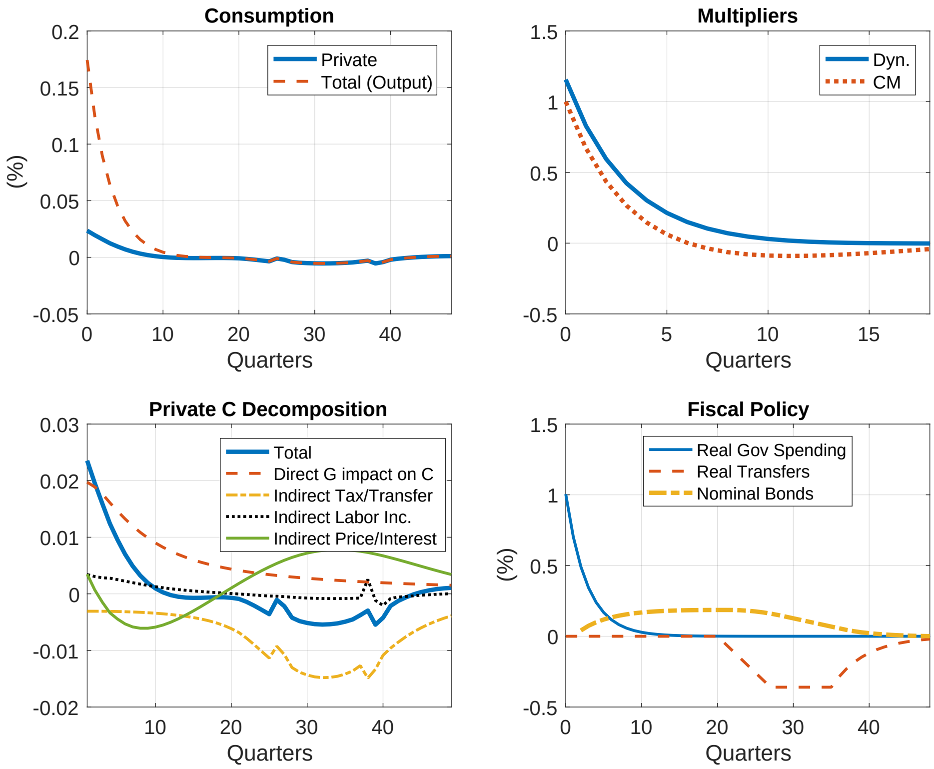


transfers to revert back to the real steady state level with an autocorrelation parameter of 0.8. Thus, under this timing scheme, the government chooses only the level of adjustment to transfers to guarantee that nominal government debt returns to its original level.

The four panels of Figure 6 summarize the main results for the aggregate consumption and output response, different multipliers, the decomposition of aggregate consumption, and government bonds.

Deficit instead of tax financing increases the initial multiplier from 0.847 to 1.156 and the initial aggregate consumption response from -0.023% to 0.024%. The decomposition of the consumption responds makes clear why. The direct impact of the spending stimulus is basically identical (0.020%) but now there is no initial offsetting effect from contemporaneously higher taxes. The total initial effect thus equals 0.0197 (-0.018% before), almost identical to the direct spending impact, leading to a larger increase in labor demand and households income. The indirect multiplier effects now accumulate to 0.003% The deficit financing leads to an

Figure 6: Fiscal Multiplier and Aggregate Consumption: Deficit Financing



increase in government bonds and the consumption response becomes negative only from period 9 onwards. However, the increase in government spending is ultimately financed through a future reduction in transfers, which results in a contraction in future output. Thus, despite the cumulated discounted multiplier is 1.081, slightly smaller than the impact multiplier. The impulse responses of the remaining variables are plotted in Figure A-2 in the appendix.

3.4 Further Analysis

We now extend the analysis in various directions. First we investigate in Section 3.4.1 how the size of the fiscal multiplier depends on the MPC by considering identical economies but with lower MPCs due to relaxed credit constraints. We then use a Taylor interest rate rule to describe monetary policy instead of a nominal interest rate fixed at the ZLB in Section 3.4.2. We then ask how the size of the fiscal multiplier depends on the timing of spending ("forward spending") and on the persistence of the stimulus in Sections 3.4.3 and 3.4.4. So far we have

Table III: Cumulated Multiplier $\overline{M}$

Tax Financing	Deficit Financing
0.63	1.08

focused - as does the literature - on the effects of an increase in government spending. Another stimulus policy is to increase transfers and we consider such policies in Section 3.4.5. Finally, we consider spending and transfer policies in a liquidity trap in Sections 3.4.6, 3.4.7 and 3.4.8. We also investigate how the size of the multiplier depends on the scale of the stimulus and on the degree of price and wage rigidities.

3.4.1 Different MPCs

Here we consider in more detail how the fiscal multiplier depends on the MPC. In our benchmark analysis the annual aggregate MPC equals 0.4. We now redo the experiments from the previous Section but with lower MPCs. To obtain lower MPPs we loosen households credit constraints. In the benchmark households constraint is zero, that is they cannot obtain any credit. We now consider credit constraints xxx including the natural borrowing limit which implies annual aggregate MPCs of xxx.

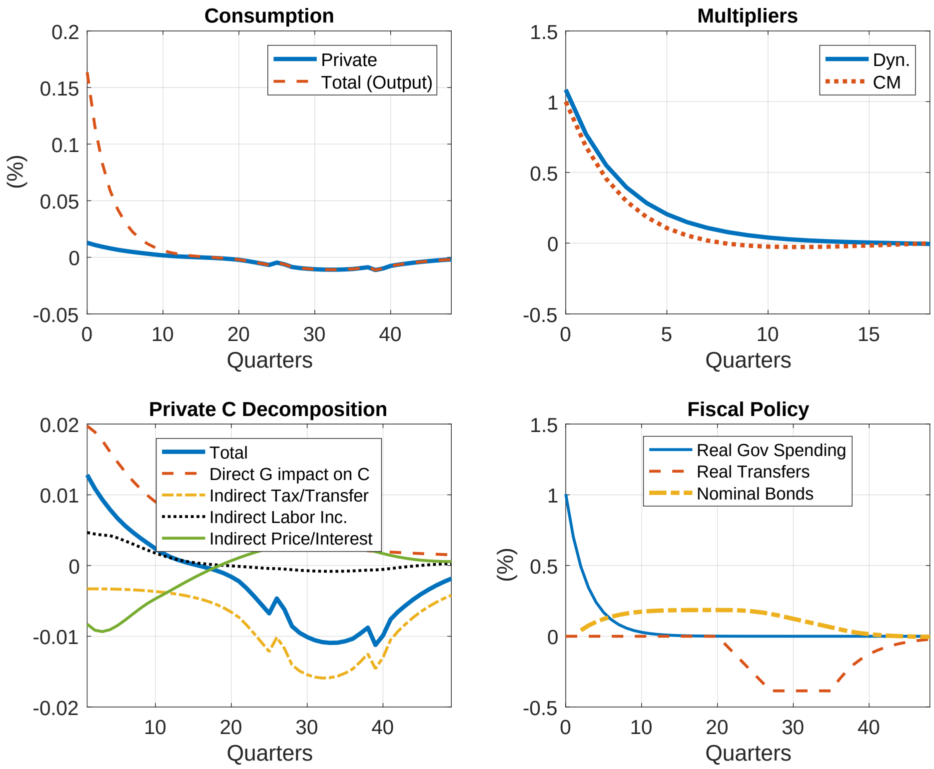
The four panel in Figure xxx show the results for the aggregate consumption response and its components and the fiscal multiplier for all the MPCs we consider. For each MPC we have one Figure which includes consumption, its components and the multiplier which is just the sum of the aggregate consumption response and the increase in government expenditures

We find ...

3.4.2 Taylor Rule

We find similar results if instead of an interest rate peg, the monetary authority follows a Taylor rule. This is not surprising since the prices respond only very little when the interest is pegged at zero. The four panels of Figure 6 summarize the main results. The impulse response

Figure 7: Fiscal Multiplier and Aggregate Consumption: Taylor Rule and Deficit Financing

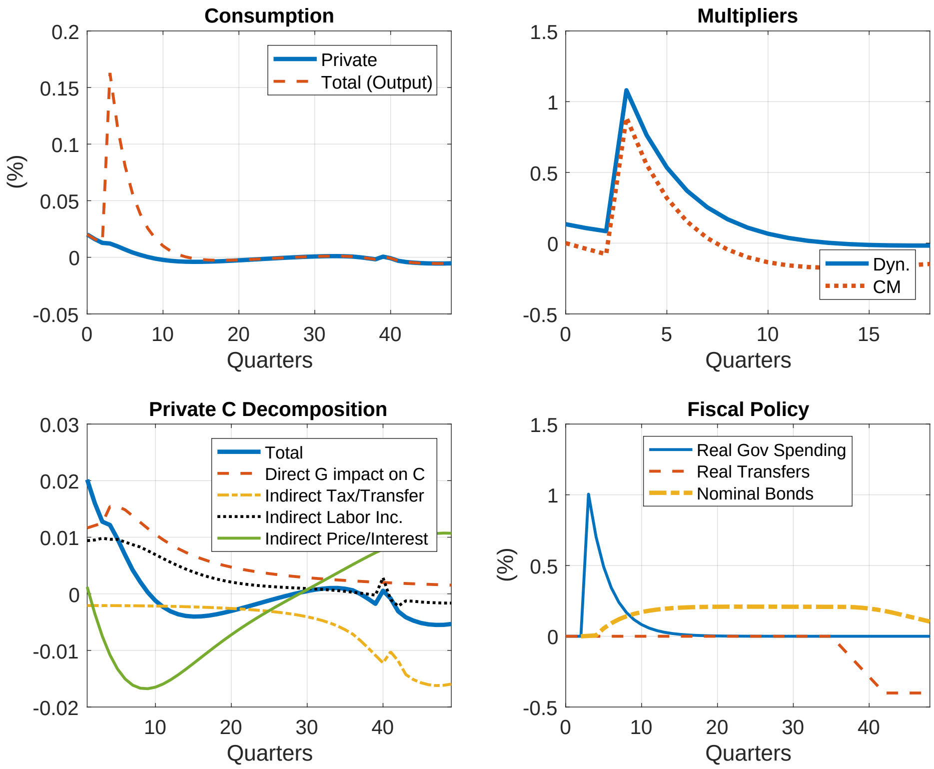


are plotted in Figure A-3.The same conclusion is reached for tax instead of deficit financing as the impulse responses in Figure A-4 show.

3.4.3 Forward Spending

The multiplier gets smaller if the spending is pre-announced to occur at a future date, 8 quarters from now. The additional spending is deficit financed. The price level now increases gradually in anticipation of the future increase in government spending such that Initially output falls before it increases at the time of the spending increase 8 quarters in the future. However, the increase in consumption as well as the multiplier at that time are smaller than the corresponding multiplier in the case when the stimulus occurs immediately and is deficit financed. The impulse responses to a spending increase 8 quarters in the future are plotted in Figure A-6 in the appendix.

Figure 8: Future (+8 quarters) spending: Deficit Financing



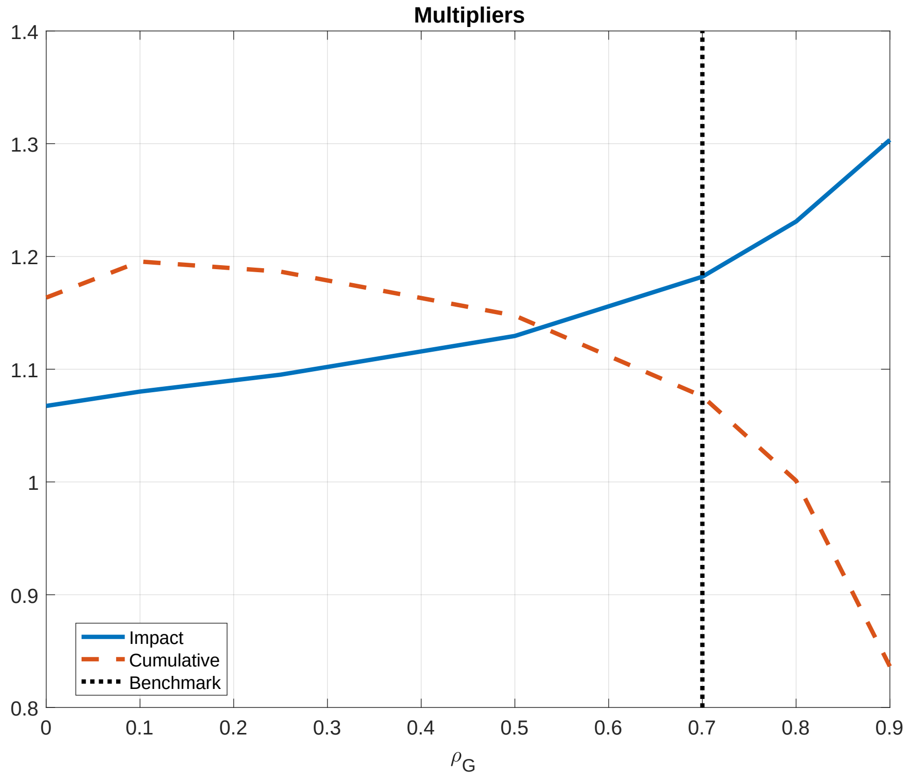
3.4.4 More Persistent Spending

We now again compute the response of prices, employment, output and consumption to a persistent increase in nominal government consumption by one percent where spending follows an AR(1) process but now with a higher persistence parameter $\rho_g = 0.9 > 0.7$. Figure A-7 in the appendix shows the impulse responses and Figure 9 the dynamic and the cumulative multiplier for various degrees of persistence

3.4.5 Transfer Multiplier

In this section we consider the multiplier in response to a one percent increase in government transfers. We assume that nominal government spending adjusts to keep real government spending constant in response to the innovation in transfers. We allow the government to finance the increase in transfers by first increasing government debt, but by increasing future transfers as in the previous section to pay back the debt.

Figure 9: Multipliers: Persistence ρ_G of spending



The impulse response is plotted in Figure A-5. The impulse response is qualitatively and quantitatively similar to the impulse response to an increase in government spending with delayed repayment. Output rises more, however, when transfers increase than when spending increases. This can be understood because, in addition to an increase in spending coming from an increase in the price level and a decline in the real rate, the heterogeneity in marginal propensities to consume means that some households will increase their spending by even more than would be implied from the fall in the real rate in a representative agent model. However, the cumulative multiplier ends up being around -0.1. As the future decrease in transfers needed to return nominal government debt to its steady state level are sufficiently contractionary to offset the contemporaneous gains.

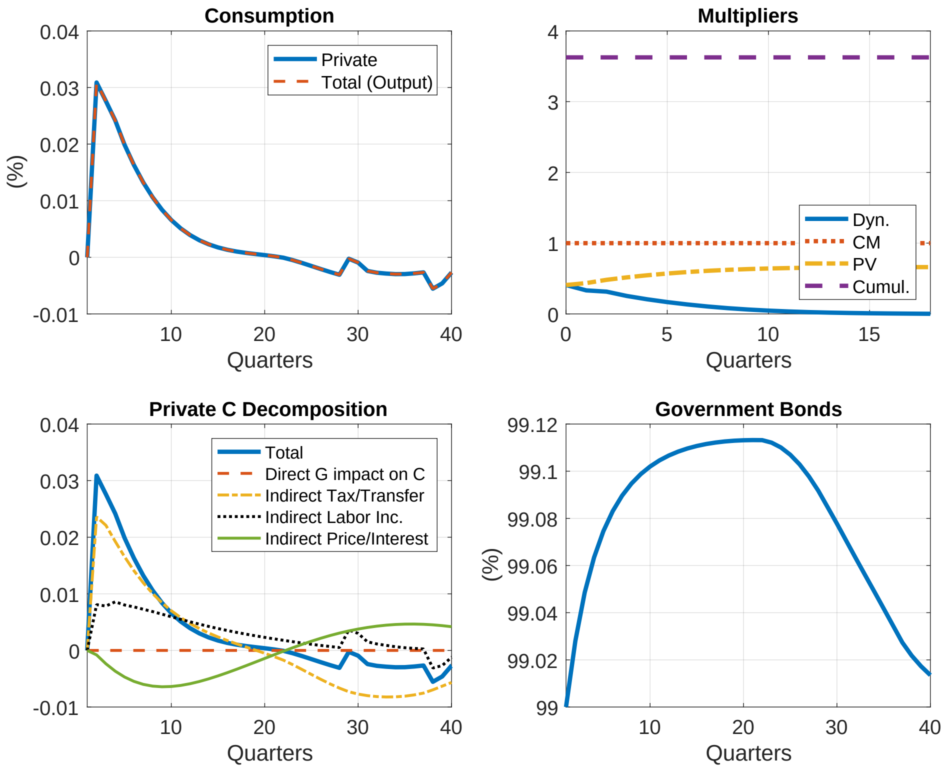
Figure 10 shows the results.

Table IV: Main Results Consumption and Multipliers

	Baseline		Taylor Rule	Forward	Transfer
	Tax-Finance	Deficit	Deficit	Deficit	Deficit
	(1)	(2)	(3)	(4)	(5)
Impact Mult.	0.8473	1.156	1.085	0.408	
Cumul	0.6315	1.081	0.841		3.626
ΔC_0	-0.0230	0.024	0.013	0.020	0.031
Decomposition of Consumption					
Direct G on C	0.0197	0.020	0.020	0.012	0
Tax/Transfers	-0.0375	-0.003	-0.003	-0.002	0.024
Indirect Income	-0.0054	0.003	0.005	0.009	0.008
Prices	0.0002	0.003	-0.008	0.001	-0.001

Note - The table contains the impact and the cumulated multiplier $\overline{M}$ as well as the initial consumption response ΔC_0. The last four rows show the decomposition of the initial aggregate consumption response into the direct G impact on C (equation 30), the effect of taxes/transfers (equation 31), indirect income effects (equation 32) and the price and interest rate effects (equation 33).

Figure 10: Transfer Multipliers (Deficit Financed)



3.4.6 Liquidity Trap

In this section we explore the extent to which the size of the multiplier may vary with other shocks hitting the economy. In particular, we consider what the government multiplier is after a demand shock. We therefore first have to generate a liquidity trap in the model, where the ZLB on nominal interest rates is binding. In doing so we follow Cochrane (2015) and construct a series of discount factors $\{\beta_t\}_{(t=1,2,...)}$ such that the natural real rate of interest - the real interest interest rate in a world with flexible prices and wages - equals -2% for 5 years and then returns to zero afterwards. All other parameters are unchanged.

We then feed the series of discount factors $\{\beta_t\}_{(t=1,2,...)}$ into our model with price and wage rigidities and calculate the response of the economy, which is shown in Figure 11. The resulting recession is quite large as output initially drops by about 5 percent. We solve for the impulse response to the demand shock under two scenarios previously considered, one - tax financing - where real government debt is kept constant and the other - deficit financing

- where we adjust transfers in the future to return back to steady state nominal debt.

Under these two scenarios, we also compute the effect of a simultaneous (at the same time as the liquidity trap starts) 1% increase in nominal government spending. Thus, we can compute the fiscal multiplier as the percent increase in output under this scenario, relative to the benchmark with no increase in spending, divided by the relative percent differences in government spending. The multipliers are plotted in the left panel of Figure 12. The right panel of Figure 12 shows the transfer multiplier, where again only deficit financing is meaningful.

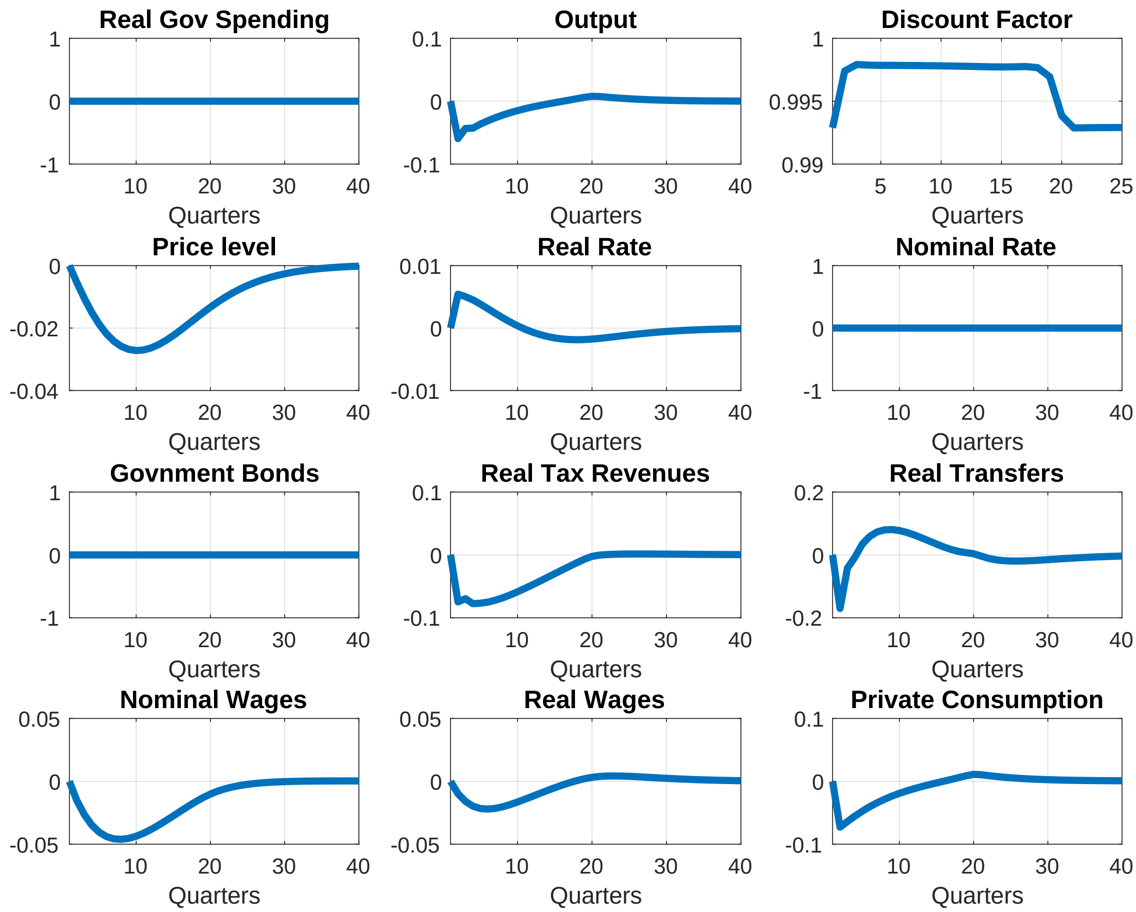
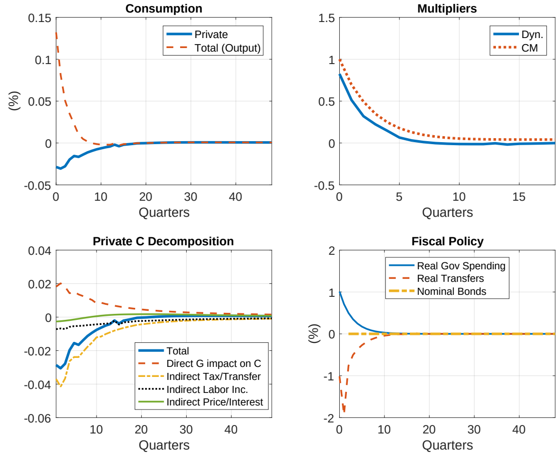


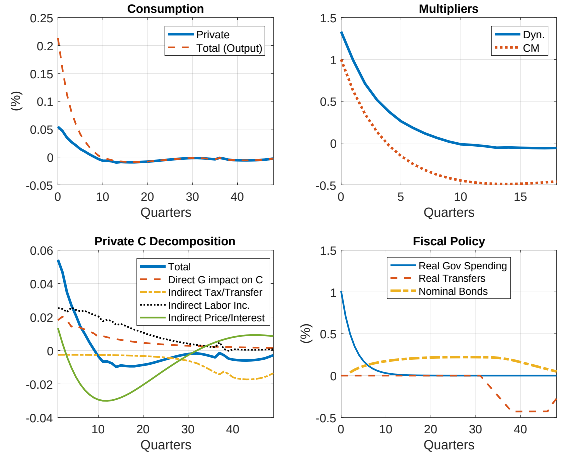
Figure 11: Economy in a Liquidity Trap

3.4.7 Scale Effects

We consider the size of the multiplier in the liquidity trap described above and how it depends on the scale of the government spending and transfer stimulus. The left panel of Figure 13 shows the government spending multiplier for a 1%, 2%, 5%, 10% increase. The right panel of Figure 13 shows the same for the transfer multiplier again for 1%, 2%, 5%, 10% increases.

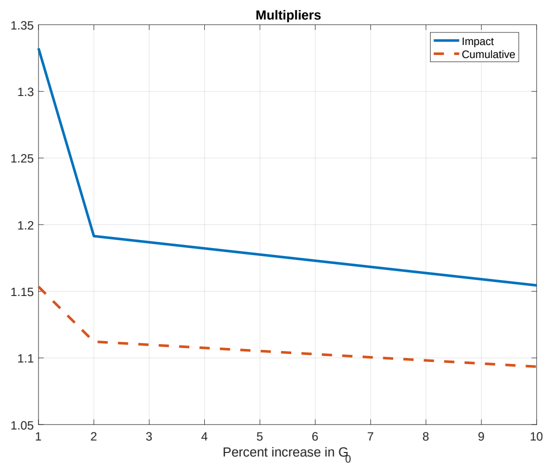


(a) Spending Multiplier (Tax Financed)

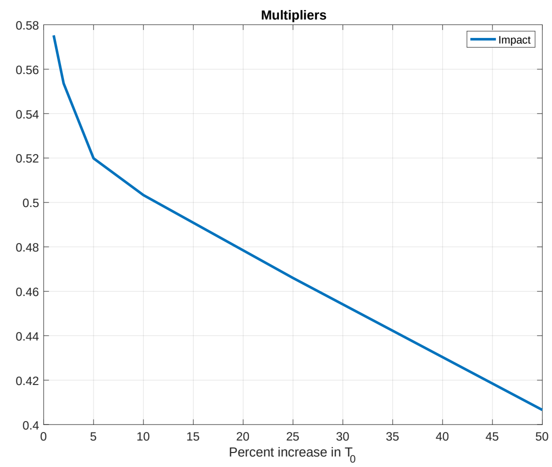


(b) Spending Multiplier (Deficit Financed) r

Figure 12: Fiscal Multipliers in a Liquidity Trap



(a) Scale of Spending



(b) Scale of Transfers

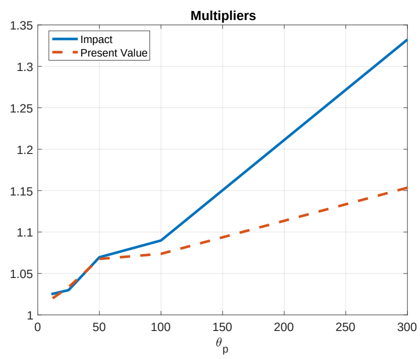
Figure 13: Multiplier in a Liquidity Trap and Scale of Spending/Transfers (Deficit Financing)

3.4.8 The degree of price and wage rigidities

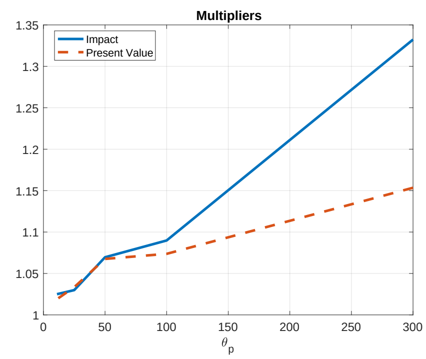
Show liquidity trap multiplier for various degrees of price and wage rigidities. The left panel of Figure 14 shows the government spending multiplier for various degrees of price rigidities, including fully flexible prices. The right panel of Figure 14 shows the same for wage rigidities.

4 Conclusions

[TO BE COMPLETED]



(a) Degree of Price Rigidities



(b) Degree of Wage Rigidities

Figure 14: Multiplier in a Liquidity Trap and Degree of Rigidities

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APPENDICES

I Figures

I.1 Impulse Responses: Main Results (Section 3.3)

Figure A-1: Impulse response to a 1% increase in nominal government spending: **Tax Financing** (Constant Nominal Debt).

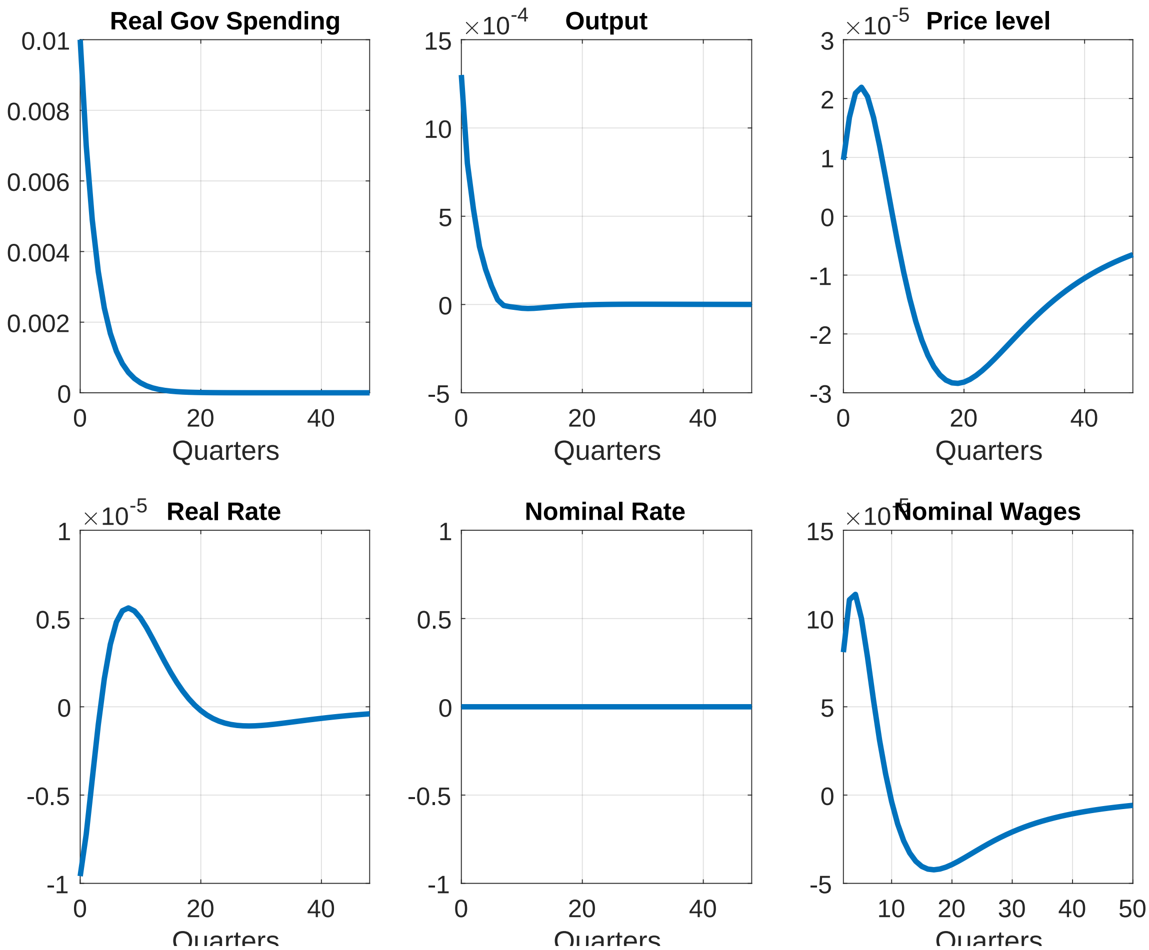
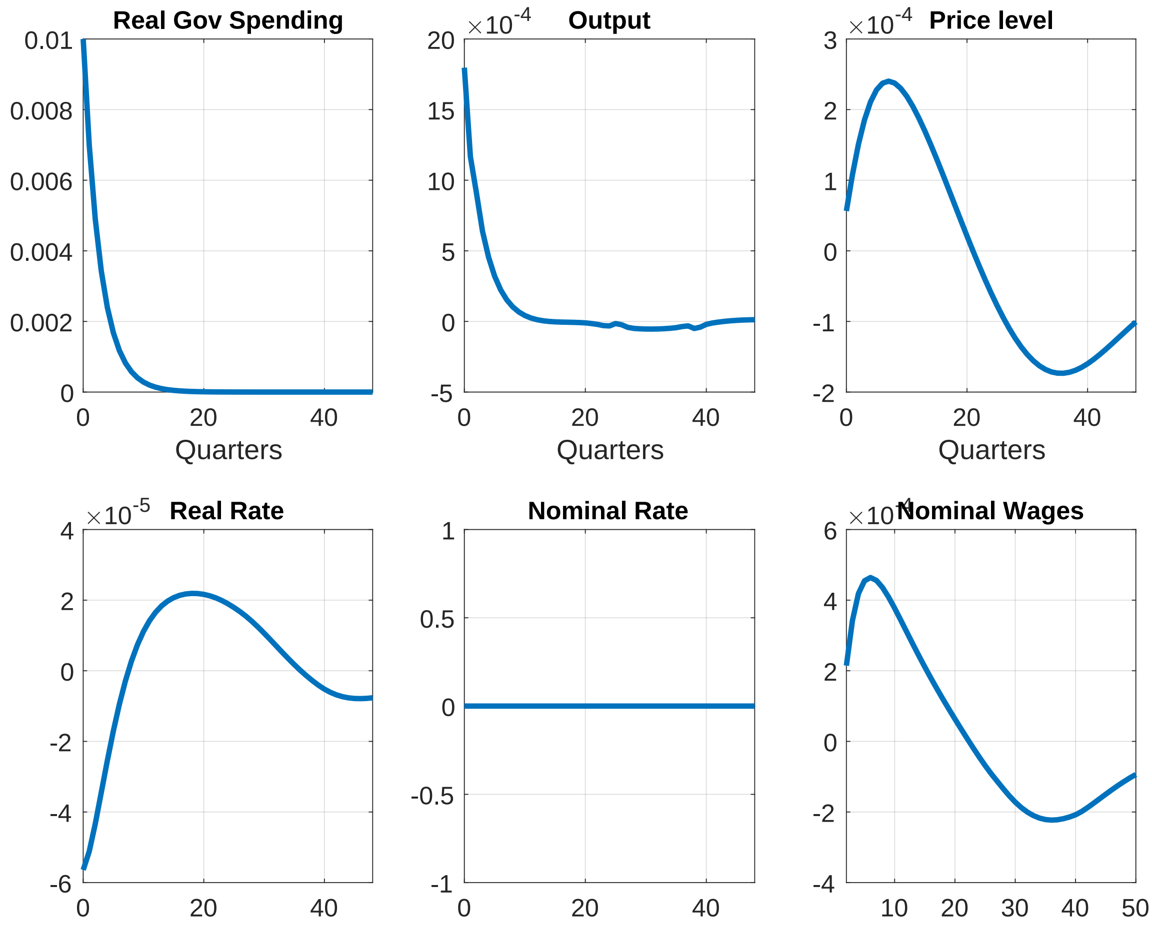


Figure A-2: Impulse response to a 1% increase in nominal government spending: **Deficit Financing**



I.2 Impulse Responses: Taylor Rule

Figure A-3: Impulse response to a 1% increase in nominal government spending: **Deficit Financing, Taylor Rule**

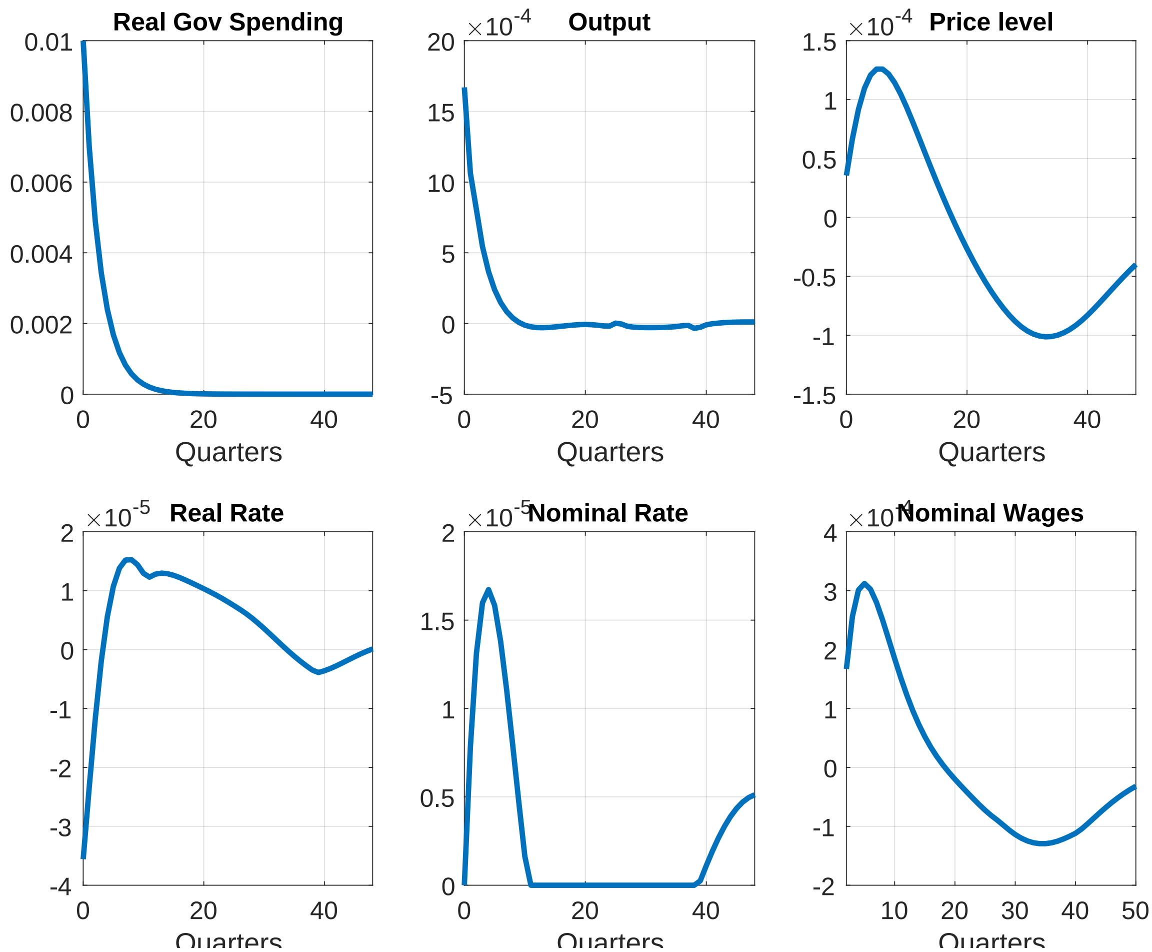
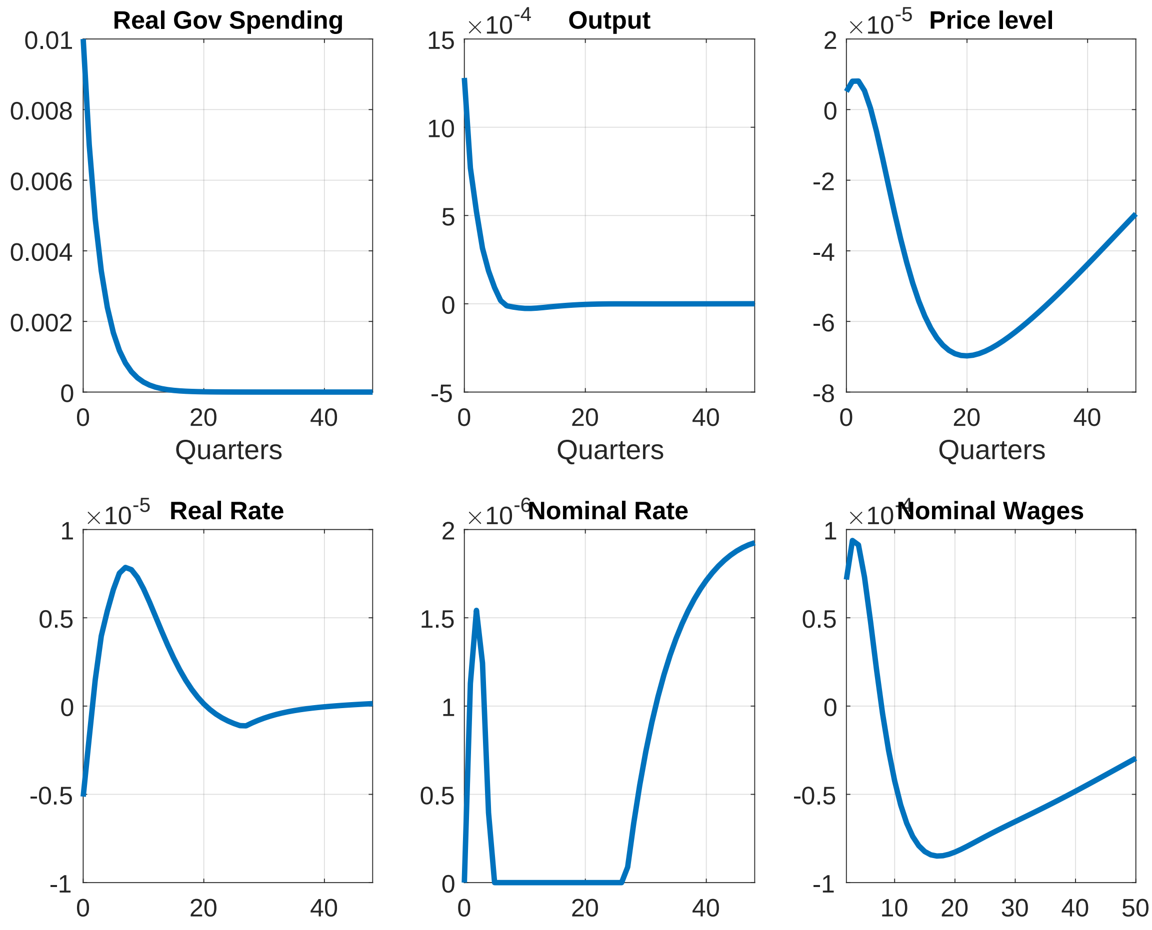
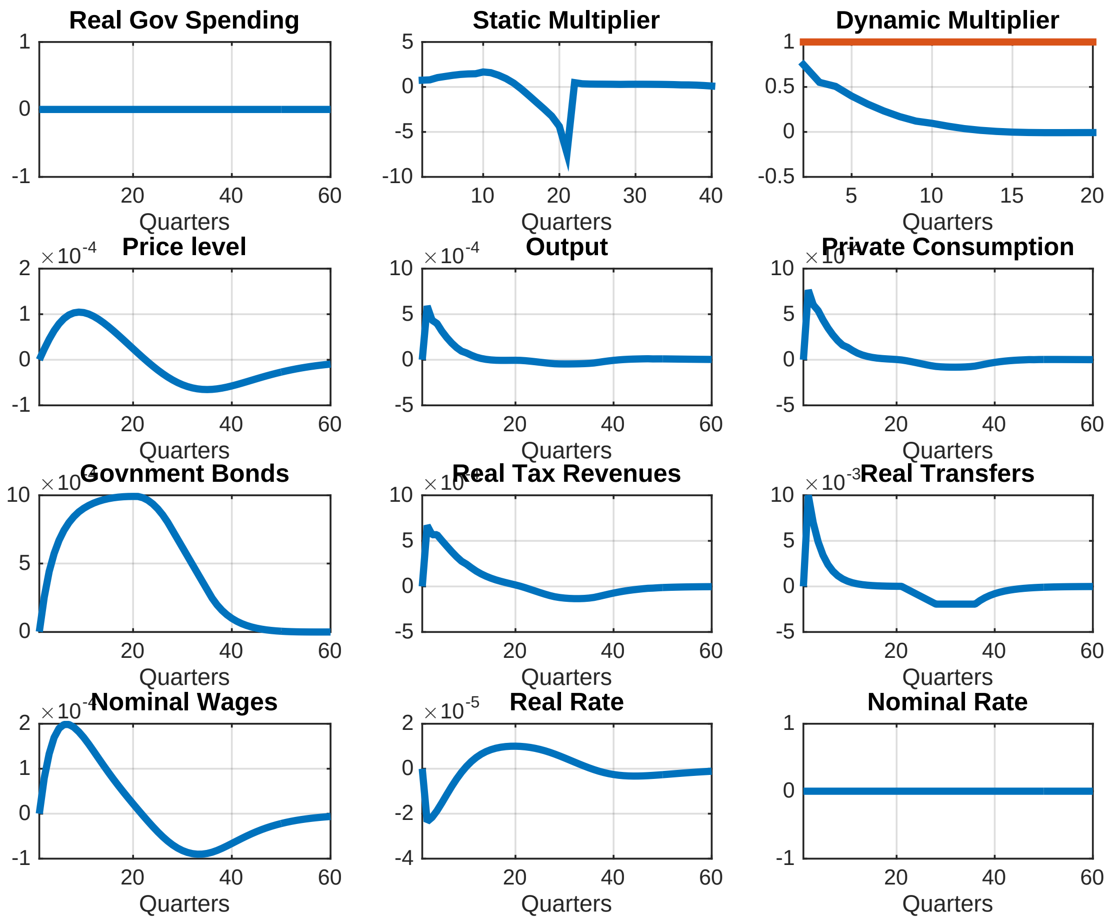


Figure A-4: Impulse response to a 1% increase in nominal government spending: **Tax Financing, Taylor Rule**



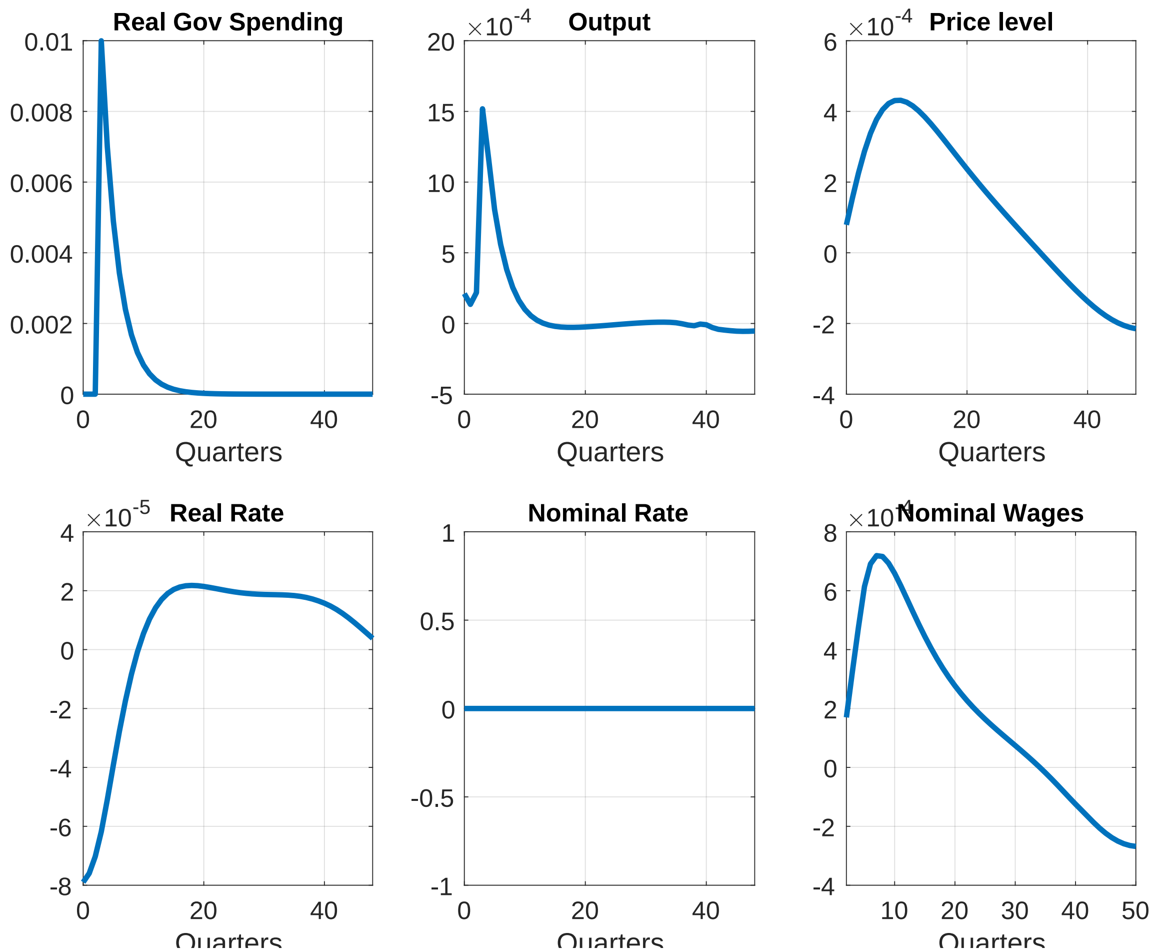
I.3 Impulse Responses: Transfer Multiplier

Figure A-5: Impulse response to a 1% increase in nominal government **Transfers**: **Deficit Financing**



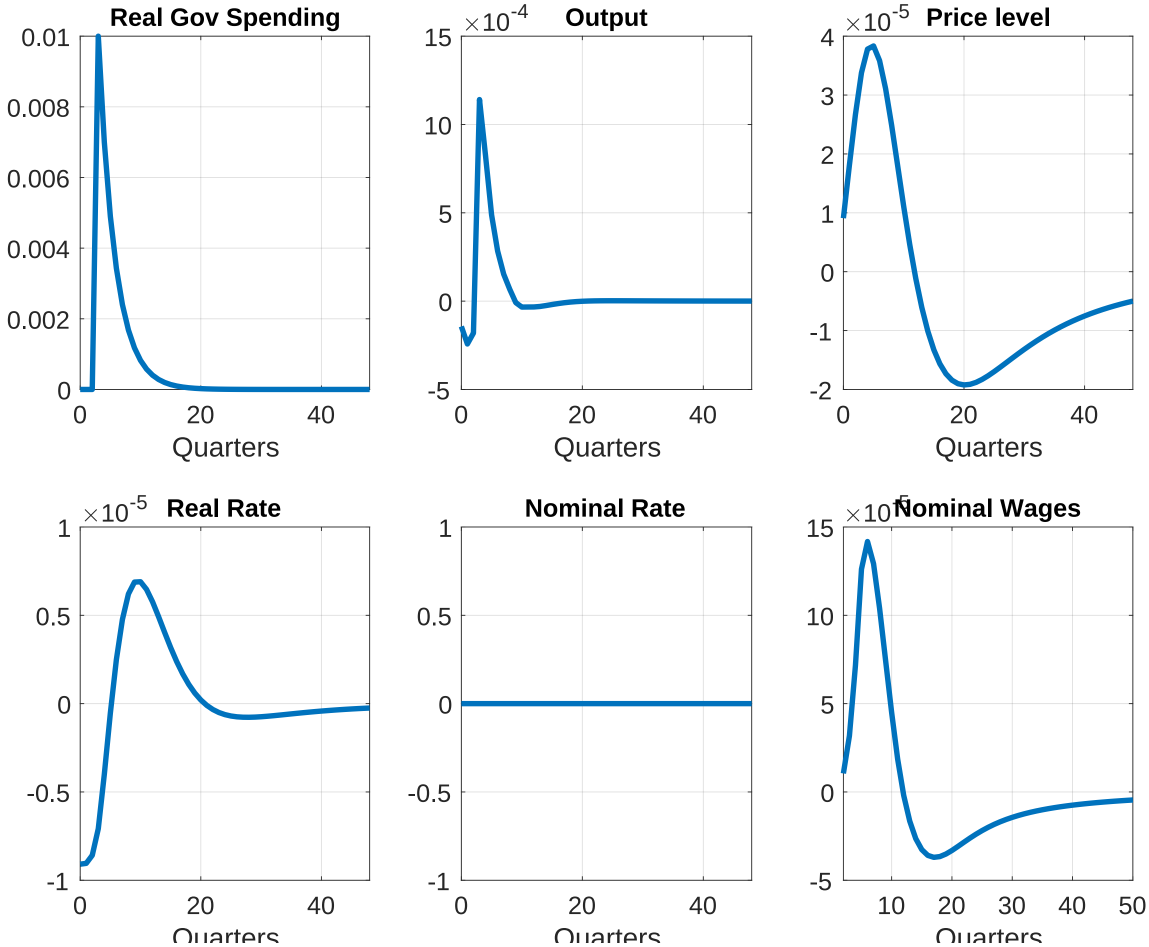
I.4 Impulse Responses: Forward Spending

Figure A-6: Impulse response to a **future** (+8 quarters) 1% increase in nominal government spending: **Deficit Financing**



I.5 Impulse Responses: Higher persistence

Figure A-7: Impulse response to a 1% increase in nominal government spending **(Persistence 0.9))**: **Deficit Financing**



II Derivations and Proofs

II.1 Derivation Pricing Equation

The firm's pricing problem is

$$V_t\left(p_{jt-1}\right) \equiv \max_{p_{jt}} \frac{p_{jt}}{P_t} y\left(p_{jt}; P_t, Y_t\right) - w_t\left(\frac{y(p_{jt}; P_t, Y_t)}{Z_t}\right)^{\frac{1}{1-\alpha}} - \frac{\theta}{2}\left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi}\right)^2 Y_t + \frac{1}{1+r_t} V_{t+1}\left(p_{jt}\right),$$

subject to the constraints $n_{jt} = \left(\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} \frac{Y_t}{Z_t}\right)^{\frac{1}{1-\alpha}}$ and $y(p_{jt}; P_t, Y_t) = \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} Y_t$.
Equivalently

$$V_t\left(p_{jt-1}\right) \equiv \max_{p_{jt}} \frac{p_{jt}}{P_t}\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} Y_t - w_t\left(\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} \frac{Y_t}{Z_t}\right)^{\frac{1}{1-\alpha}} - \frac{\theta}{2}\left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi}\right)^2 Y_t + \frac{1}{1+r_t} V_{t+1}\left(p_{jt}\right),$$

The FOC w.r.t p_{jt}

$$(1-\epsilon)\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} \frac{Y_t}{P_t} + \frac{\epsilon}{1-\alpha} w_t \left(\frac{p_{jt}}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}-1} \left(\frac{Y_t}{Z_t P_t}\right)^{\frac{1}{1-\alpha}} - \theta\left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi}\right) \frac{Y_t}{p_{jt-1}} + \frac{1}{1+r_t} V'_{t+1}(p_{jt}) = 0 \tag{A1}$$

and the envelope condition

$$V'_{t+1} = \theta\left(\frac{p_{jt+1}}{p_{jt}} - \overline{\Pi}\right) \frac{p_{jt+1}}{p_{jt}} \frac{Y_{t+1}}{p_{jt}}. \tag{A2}$$

Combining the FOC and and the envelope condition

$$\begin{aligned} &(1-\epsilon)\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} \frac{Y_t}{P_t} + \frac{\epsilon}{1-\alpha} w_t \left(\frac{p_{jt}}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}-1} \left(\frac{Y_t}{Z_t P_t}\right)^{\frac{1}{1-\alpha}} \\ - \; &\theta\left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi}\right) \frac{Y_t}{p_{jt-1}} + \frac{1}{1+r_t}\theta\left(\frac{p_{jt+1}}{p_{jt}} - \overline{\Pi}\right) \frac{p_{jt+1}}{p_{jt}} \frac{Y_{t+1}}{p_{jt}} = 0 \end{aligned} \tag{A3}$$

Using that all firms choose the same price in equilibrium

$$\begin{aligned} &(1-\epsilon) + \frac{\epsilon}{1-\alpha} w_t Z_t^{\frac{1}{\alpha-1}} \left(\frac{Y_t}{P_t}\right)^{\frac{\alpha}{1-\alpha}} \\ - \; &\theta\left(\pi_t - \overline{\Pi}\right)\pi_t + \frac{1}{1+r_t}\theta\left(\pi_{t+1} - \overline{\Pi}\right)\pi_{t+1} \frac{Y_{t+1}}{Y_t} = 0 \end{aligned} \tag{A4}$$

II.2 Derivation Wage Equation

$$\Theta\left(s_{jt}, W_{jt}, W_{jt-1}; Y_t\right) = s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t.$$

The middleman's wage setting problem is to maximize

$$\begin{aligned}
& V_t^w\left(\hat{W}_{t-1}\right) \\
\equiv\ & \max_{\hat{W}_t} \int \Big(\frac{s_{jt}(1-\tau_t)\hat{W}_t}{P_t} h(\hat{W}_t; W_t, H_t) - s_{jt} g(h(\hat{W}_t; W_t, H_t)) dj - \int s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t dj \\
+\ & \frac{1}{1+r_t} V_{t+1}^w\left(\hat{W}_t\right), \qquad \text{(A5)}
\end{aligned}$$

where $h_{jt} = h(W_{jt}; W_t, H_t) = \left(\frac{W_{jt}}{W_t}\right)^{-\epsilon_w} H_t$.

The FOC w.r.t $\hat{W}_t$

$$(1-\tau_t)(1-\epsilon_w)\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w}\frac{H_t}{P_t} + \epsilon_w g'(h(\hat{W}_t; W_t, H_t))\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w - 1}\frac{H_t}{W_t} \qquad \text{(A6)}$$

$$-\theta_w\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi^w}\right)\frac{H_t}{\hat{W}_{t-1}} + \frac{1}{1+r_t}V'_{t+1}(\hat{W}_t) = 0$$

$$\text{(A7)}$$

and the envelope condition

$$V'_{t+1} = \theta_w\left(\frac{\hat{W}_{t+1}}{\hat{W}_t} - \overline{\Pi^w}\right)\frac{\hat{W}_{t+1}}{\hat{W}_t}\frac{H_{t+1}}{\hat{W}_t}, \qquad \text{(A8)}$$

where we have used that $\int s = 1$.

Combining the FOC and and the envelope condition

$$\begin{aligned}
& (1-\tau_t)(1-\epsilon_w)\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w}\frac{H_t}{P_t} + \epsilon_w g'(h(\hat{W}_t; W_t, H_t))\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w - 1}\frac{H_t}{W_t} \\
- \ & \theta_w\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi^w}\right)\frac{H_t}{\hat{W}_{t-1}} + \frac{1}{1+r_t}\theta_w\left(\frac{\hat{W}_{t+1}}{\hat{W}_t} - \overline{\Pi^w}\right)\frac{\hat{W}_{t+1}}{\hat{W}_t}\frac{H_{t+1}}{\hat{W}_t} = 0 \qquad \text{(A9)}
\end{aligned}$$

Using that $\hat{W}_t = W_t$, $\pi_t^w = \frac{W_t}{W_{t-1}} = \frac{\hat{W}_t}{\hat{W}_{t-1}}$ and $h_{jt} = H_t$:

$$\begin{aligned} &(1-\tau_t)(1-\epsilon_w)\frac{W_t}{P_t} + \epsilon_w g'(h(\hat{W}_t; W_t, H_t)) \\ - \quad & \theta_w \left(\pi_t^w - \overline{\Pi^w}\right)\pi_t^w + \frac{1}{1+r_t}\theta_w \left(\pi_{t+1}^w - \overline{\Pi^w}\right)\pi_{t+1}^w \frac{H_{t+1}}{H_t} = 0 \end{aligned} \tag{A10}$$

III GHH Preferences

In this Section of the appendix we explore the multiplier for different preferences. We assume that households have identical GHH preferences for leisure nested within constant relative risk aversion (CRRA) preferences for non-durable consumption:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, h_t, s_t)$$

where:

$$u(c,h) = \begin{cases} \frac{(c - s_t g(h_t))^{1-\sigma} - 1}{1-\sigma} & \text{if } \sigma \neq 1 \\ \log(c - s_t g(h_t)) & \text{if } \sigma = 1. \end{cases}$$

Except for the wage setting all model parts remain unchanged. The middleman's wage setting problem is slightly changed to

$$\begin{aligned} & V_t^w\left(\hat{W}_{t-1}\right) \\ \equiv \quad & \max_{\hat{W}_t} \int \Big(\frac{s_{jt}(1-\tau_t)\hat{W}_t}{P_t} h(\hat{W}_t; W_t, H_t) - s_{jt} g(h(\hat{W}_t; W_t, H_t)) dj - \int s_{jt} \frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t dj. \\ + \quad & \frac{1}{1+r_t} V_{t+1}^w\left(\hat{W}_t\right), \end{aligned} \tag{A11}$$

and the wage inflation equation becomes

$$\theta_w \left(\pi_t^w - \overline{\Pi^w}\right)\pi_t^w = (1-\tau_t)(1-\epsilon_w) w_t + \epsilon_w g'(h(\hat{W}_t; W_t, H_t)) + \frac{1}{1+r_t}\theta_w \left(\pi_{t+1}^w - \overline{\Pi^w}\right)\pi_{t+1}^w \frac{H_{t+1}}{H_t}.. \tag{A12}$$