The Fiscal Multiplier*

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Abstract

This paper studies the size of the fiscal multiplier in a model with incomplete markets and sticky prices. Allowing for incomplete markets instead of complete markets—the prevalent assumption in the literature—comes with two advantages. First, the incomplete markets model delivers 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. Second, in our model the response of prices, output, consumption and employment is uniquely determined by fiscal policy for any monetary policy as opposed to most of the previous literature, where there can exist an infinite number of equilibria, leaving the researcher to arbitrarily pick one. Our preliminary findings indicate a much smaller fiscal multiplier than commonly found in past studies.

Keywords: Fiscal Multiplier, Incomplete Markets, Sticky Prices

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1 Introduction

How does an increase in government spending affect output, employment and investment? This classic question has been addressed in numerous empirical and theoretical papers with a renewed interest in the aftermath of the Great Recession.

The effects of government spending on output are usually summarized as the fiscal multiplier, which describes the percentage increase in output in response to a one percent increase in government spending. Despite the importance of this research question no consensus on the size of the multiplier has been reached and findings come with a lot of uncertainty (see Ramey (2011) for a survey).

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 correctly, the size of the local multipliers found in those studies may be not very informative about the magnitude of aggregate multipliers. For example the local multiplier could be 1.5 whereas the aggregate multiplier is 0.

Furthermore, "the fiscal multiplier" is not a single number—as its size depends very much 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. Important details which are hard to control for in empirical studies.

As a response to the difficulties faced in empirical work, a more theoretical approach has emerged which computes the fiscal multiplier in New Keynesian models with sticky prices and sticky wages. In a theoretical model it is easy to control for all details of the fiscal policy which are important to assess its efficacy, overcoming the difficulties one faces in empirical work.

One of the main limitations of the New Keynesian models used thus far for policy analysis is that the households in the model economies are representative agents. The households behave exactly like permanent-income households—as a result there is no heterogeneity in the marginal propensity to consume (MPC). Further, the MPC in response to 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.

In this paper we build on this insight and extend the standard Bewley-Imrohoroglu-Huggett-Aiyagari model to include New-Keynesian style nominal price rigidities. Introducing incomplete markets allows the model to match the rich joint distribution of income, earnings and wealth. Further, such heterogeneity is crucial in generating a realistic distribution of MPCs.

While allowing for heterogeneity will overcome one shortcoming over the existing theoretical literature, a second problem was pointed out by Cochrane (2015). He studies fiscal policy in new-Keynesian models during a liquidity trap and shows that the policy predictions depend strongly on the choices made by the researcher to select a specific equilibrium. Depending on these choices, the fiscal multiplier can be arbitrarily large or even negative. The root of this problem is clear. The price level is indeterminate and therefore the researcher has to select one equilibrium where at the same time a continuum of other choices with very different policy predictions are possible. This renders this class of models not very useful for a policy analysis.

To overcome this second challenge, we leverage the insight of Hagedorn (2016) who shows that incomplete markets combined with fiscal policy specified partially in nominal terms delivers a globally determined price level—so that the researcher does not have to pick a specific equilibrium. Instead the price level is uniquely and jointly determined by fiscal and monetary policy. This determinacy result enables the researcher to study arbitrary policies and how they affect the economy, including a constant nominal interest rate that would lead to indeterminacy in the standard approach.

Thus, our paper is the first to quantify the size of the fiscal multiplier in the presence of significant household heterogeneity and in a model with a uniquely determined price level which predicts a unique equilibrium in response to a stimulus. Further, using an incomplete markets model 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.

Our preliminary findings indicate a much smaller fiscal multiplier than commonly found in past studies. To understand this result it is instructive to recall how the size of the multiplier is determined in New Keynesian models with complete markets.

Farhi and Werning (2013) show that if the nominal interest rate is pegged, the size of the multiplier is one-to-one related to the accumulated response of inflation which is induced by the fiscal stimulus. In our incomplete markets model the path of prices and therefore also the accumulated response of inflation is uniquely determined by monetary and fiscal policy. We can then use this implied path of inflation rates and ask what this inflation path would imply in a model with complete markets, that is if we selected this equilibrium out of the many possible choices there. For example, suppose that the price level eventually returns to its pre-stimulus steady state level and that the initial price response is positive, then the accumulated inflation rate and therefore the fiscal multiplier would be smaller than 1 in the complete markets model.

But this is not the multiplier in the model with incomplete markets as the derivation for complete markets does not apply here. Since wealth is heterogenous and credit constraints are binding occasionally, one cannot iterate using the consumption Euler equation of the representative household as Farhi and Werning (2013) do in their model with complete markets. Instead the stimulus policy has distributional consequences which since marginal propensities to consume are heterogenous affect aggregate consumption and thus also employment.

An increase in spending and the resulting responses of prices and hours operate through various distributional channels. 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. This redistribution happens for two reasons. First, the demand stimulus leads to more demand for labor and thus pushes wages up but does not change income from holdings bonds, the only asset. As a result households benefit the more the more they depend on labor income to finance their consumption. The second reason is that the increase in prices lowers the real value of nominal assets, what affect asset holders the more the more nominal assets they hold and does not affect labor income at all. The redistribution of income matters since the marginal propensity to consume differs across households. In particular credit-constrained households are hand-to-mouth and have a marginal propensity

of one whereas asset-rich households have a low propensity similar to a permanent-income-hypothesis household, implying an increase in demand through this redistribution. Thus this channel suggest a multiplier larger than the one implied by the accumulated inflation rate.

However, there is another, as it turns out quantitatively important, channel. The demand stimulus in combination with price stickiness implies large swings in the mark-up and thus in profits. A quantitative assessment of a fiscal stimulus therefore depends on who is the claimant of these profits and more generally on the distributional consequences of the change in profits. We assume that profits are fully taxed. Then there are at least three possibilities how the government can use these tax receipts, corresponding to the three tax instruments available: transfers, labor subsidies and capital income subsidies. In our benchmark the taxed profits are use to pay lump-sum transfers. In another scenario the revenue from taxing profits is used to subsidize asset income which effectively makes asset holders the owner of the firms. We will also explore a subsidy to labor income, the standard assumption in new Keynesian models.

The paper is organized as follows. Section 2 presents our incomplete markets model with price 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. Section 4 extends the basic model and we add capital accumulation and allow for habit persistence and sticky wages.

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. Later when we allow for sticky

wages as well, we 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 identical GHH preferences for leisure nested within constant relative risk aversion (CRRA) preferences for non-durable consumption:

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

where:

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

and $\beta \in (0,1)$ is the discount factor. 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 bond market for a nominal rent i and a real return $(1+r) = \frac{1+i}{1+\pi}$, where $1+\pi = \frac{P'}{P}$ is the inflation rate.

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

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

where τ_t is a proportional labor tax and T_t is a nominal lump sum transfer. Agents are price takers. Thus, we can rewrite the agent's problem recursively as follows:

$$\begin{aligned} V(a,s;\Omega) = \max_{c\geq 0, h\geq 0, a'\geq 0} & u(c,l) + \beta \sum_{s\in\mathcal{S}} p(s'|s) V(a',s';\Omega') \\ \text{subj. to} \quad & Pc + a' = (1+i)a + P(1-\tau)whs + T \\ & \Omega' = \Gamma(\Omega) \end{aligned} \tag{1}$$

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

$$y_{jt} = y(p_{jt}; P_t, Y_t) = \left(\frac{p_{jt}}{P_t} \right)^{-\epsilon} Y_t, \tag{2}$$

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

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

Intermediate good producer Each intermediate good j is produced by a monopolistically competitive producer using labor input n_j. Production technology is linear.

$$y_{jt} = Z_t n_{jt}^{1-\alpha}$$

where Z_t is aggregate productivity. Intermediate producers hire labor at the nominal wage $P_t w_t$ in a competitive labor market. With this technology, the marginal cost of a unit of intermediate good is

$$mc_{jt} = \frac{w_t}{Z_t (1-\alpha) n_{jt}^{\alpha}}.$$

Each firm chooses its price to maximize profits subject to price adjustment costs as in Rotemberg (1982). These adjustment costs are measured in units of aggregate output and are given by a quadratic function of the change in prices above and beyond steady state inflation $\overline{\Pi}$,

$$\Theta\left(p_{jt}, p_{jt-1}; Y_t\right) = \frac{\theta}{2} \left(\frac{p_{jt}}{p_{jt-1}} - \overline{\Pi} \right)^2 Y_t$$

Given last period's individual price p_{jt-1} and the aggregate state $(P_t, Y_{t,}, w_t, r_t)$, the firm

chooses this period's price p_{jt} to maximize the present discounted value of future profits. The firm satisfies all demand,

$$y(p_{jt}; P_t, Y_t) = Z_t n(y(p_{jt}; P_t, Y_t))^{1-\alpha} \tag{3}$$

by hiring the necessary amount of labor,

$$n_{jt} \;=\; n(y(p_{jt}; P_t, Y_t)) = (\frac{y(p_{jt}; P_t, Y_t)}{Z_t})^{\frac{1}{1-\alpha}} = (\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon} \frac{Y_t}{Z_t})^{\frac{1}{1-\alpha}} \tag{4}$$

The firm's pricing problem is

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

where Φ are fixed operating costs. In equilibrium all firms choose the same price, and thus, aggregate consistency implies $p_{jt} = P_t$ for all j and t. Thus, $\frac{p_{jt}}{p_{jt-1}} = \frac{P_t}{P_{t-1}} = \pi_t$ and $\frac{p_{jt+1}}{p_{jt}} = \frac{P_{t+1}}{P_t} = \pi_{t+1}$.

Some algebra (delegate to the appendix) yields the New Keynesian Phillips Curve

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

The equilibrium real profit of each intermediate goods firm is then

$$d_t = Y_t - \Phi - w_t(\frac{Y_t}{Z_t})^{\frac{1}{1-\alpha}} - \frac{\theta}{2}\left(\Pi_t - \overline{\Pi}\right)^2 Y_t$$

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:

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

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:

$$B^g_{t+1} = (1 + i_t)B^g_t + G_t - P_t d_t - \int \tilde{T}_t(w_t s_t h_t) d\Omega. \tag{5}$$

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 equals the amount of assets provided by households:

$$B_{t+1} = \int_{a_t} \sum_{s_t \in \mathcal{S}} a_{t+1}(a_t, s_t) d\Omega_t(a_t, s_t) \tag{6}$$

$$H_t = \int_{a_t} \sum_{s_t \in \mathcal{S}} s_t h_t(a_t, s_t) d\Omega_t(a_t, s_t) \tag{7}$$

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, and similarly $h_t(a_t, s_t)$ is the associated labor policy function.

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 $v_t : X \times \mathcal{M} \to \mathcal{R}$, policy functions $a_t : X \times \mathcal{M} \to \mathcal{R}_+$ and $c_t : X \times \mathcal{M} \to \mathcal{R}_+, h_t : X \times \mathcal{M} \to \mathcal{R}_+$, $H_t : A \to \mathcal{R}_+$, pricing functions $r_t : A \to \mathcal{R}$ and $w_t : A \to \mathcal{R}_+$, and law of motion $\Gamma : A \to A$, such that:

1. v_t satisfies the Bellman equation with corresponding policy functions a_t, c_t, h_T given price sequences $r_t(), w_t()$

2. $w_t()$ and $h_t()$ satisfy:

$$w_t(\Omega_t)s(1 - \tau_t) \quad = \quad g'(h_t(s, ...))$$

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

$$\begin{aligned} B_{t+1} &= \int a_{t+1}(a, s; \Omega_t) d\Omega_t \\ H_t(\Omega_T) &= \int s h_t d\Omega_t \\ Y_t = Z_t H_t^{1-\alpha} &= \int c(a, s; \Omega) d\Omega_t + \frac{G}{P} + \Phi + \frac{\theta}{2} \left(\Pi_t - \overline{\Pi}\right)^2 Y_t \end{aligned}$$

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

3 The Fiscal Multiplier

Before we compute the fiscal multiplier in our model with incomplete markets, it is instructive to recall how the size of the multiplier is determined in New Keynesian models with complete markets as this allows us to better understand our results.

Fiscal Multiplier with Complete Markets

Farhi and Werning (2013) show that if the nominal interest rate is pegged, the size of the multiplier m is determined by the response of the inflation rate only. They start from the Consumption Euler equation for a utility function, $\frac{C^{1-\sigma}}{1-\sigma} + ...$

$$C_t^{-\sigma} = \beta \frac{1 + i_{ss}}{1 + \pi_{t+1}} C_{t+1}^{-\sigma}. \tag{8}$$

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,

$$C_1^{-\sigma} = \Big(\prod_{t=1}^{T-1} \big(\beta \frac{1 + i_{ss}}{1 + \pi_{t+1}} \big) \Big) C_T^{-\sigma}, \tag{9}$$

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

$$m = \frac{C_1}{C_{ss}} = \Big(\prod_{t=1}^{T-1} \frac{1 + \pi_{t+1}}{\beta(1 + i_{ss})} \Big)^{\frac{1}{\sigma}} = \Big(\prod_{t=1}^{T-1} \frac{1 + \pi_{t+1}}{1 + \pi_{ss}} \Big)^{\frac{1}{\sigma}} \tag{10}$$

where we have used that $\beta \frac{1+i_{ss}}{1+\pi_{ss}} = 1$. As a result the size of the fiscal multiplier is one-to-one

related to the accumulated response of inflation which is induced by the fiscal stimulus,

$$m^{\sigma} = \prod_{t=1}^{T-1} \frac{1+\pi_{t+1}}{1+\pi_{ss}}. \tag{11}$$

However, as Cochrane (2015) has pointed out, the model does not predict a unique outcome for the path of inflation in response to a fiscal stimulus but instead a continuum of equilibria exists. What renders this problematic for a study of fiscal policy is that the size of the fiscal multiplier can be very different across these equilibria, ranging from arbitrarily large to even negative. In other words the researcher has to select a specific equilibrium and thus implicitly chooses the size of the multiplier. The root of this problem is well known. The price level is indeterminate that is a continuum of price levels satisfies the equilibrium restrictions.

Unique Equilibrium with Incomplete Markets

The results in Hagedorn (2016) however imply that these problems are overcome in models with incomplete market models such as ours since the price level is determinate in these type of models. It is easy to see how the arguments in Hagedorn (2016) apply to our model and deliver a determinate steady state price level. In both complete and incomplete market models a Fisher relation between the steady state nominal interest i_{ss}, real interest rate r_{ss} and inflation π_{ss} holds:

$$(1+i_{ss}) = (1+r_{ss})(1+\pi_{ss}), \tag{12}$$

with an important difference between complete and incomplete markets. If markets were complete the real interest rate is determined by the discount factor only, $(1+r_{ss})\beta = 1$, whereas in incomplete market models the real interest rate depends on virtually all model primitives such as preferences, uncertainty, etc. and also on fiscal policies G_{ss}/P_{ss}, T_{ss}/P_{ss} and B_{ss}/P_{ss}, so that the above equation in our incomplete markets models can be written as

$$\frac{1+i_{ss}}{1+\pi_{ss}} = (1+r_{ss}(G_{ss}/P_{ss}, T_{ss}/P_{ss}, B_{ss}/P_{ss}, \ldots)). \tag{13}$$

This equation together with the steady state condition that the growth rate of nominal spending, nominal taxes and nominal debt is equal to the inflation rate (in the absence of economic growth),

$$1+\pi_{ss} = \frac{G'-G}{G} = \frac{T'-T}{T} = \frac{B'-B}{B}, \tag{14}$$

determine, given monetary and fiscal policy, the two unknown variables, the inflation rate π_{ss} and the price level P_{ss}. Note that equation (14) implies that the inflation rate is set by fiscal policy and is equal to the growth rate of nominal government spending. The price level then adjust such that equation (13) holds, that is that the real interest rate $1+r_{ss}$ is equal to $\frac{1+i_{ss}}{1+\pi_{ss}}$.

The finding that the real interest rate depends on the price level in incomplete market models is due to the failure of the permanent income hypothesis and that agents, as a result of this failure, engage in precautionary savings. The intuition is straightforward. A higher steady state price level lowers real government consumption since fiscal policy is nominal and at the same time lowers the tax burden for the private sector by the same amount. Households however do not spend all of the tax rebate on consumption but instead use some of the tax rebate to increase their precautionary savings. This less than one-for-one substitution of private sector demand for government consumption implies a drop in aggregate demand, requiring an adjustment of the real interest rate to stimulate demand such that it equals supply. As explained above, however, the steady state real interest rate cannot adjust to equate supply and demand as it is pinned down by the nominal interest rate set by monetary policy and the inflation rate which is equal to the growth rate of nominal government spending. Therefore the price level has to adjust such that demand equals supply when the real interest rate equals r_{ss}.

This determinacy result implies that both the price level in the steady state before the fiscal stimulus, P_{ss}, and the price level in the new steady state, P_{ss}^{new} to which the economy converges after the stimulus has died out are uniquely and jointly determined by fiscal and monetary policies. What is important for our aim to compute the fiscal multiplier is that in our model the accumulated inflation rate is also uniquely determined by policy since it is equal to the ratio of the new steady state price level and the the price level in the initial period (which is different from P_{ss}),

$$\frac{P_{ss}^{new}}{P_1} = \prod_{t=1}^{T-1} \frac{1+\pi_{t+1}}{1+\pi_{ss}} = \prod_{t=1}^{T-1}(1+\pi_{t+1}). \tag{15}$$

Furthermore the model delivers unique responses of prices, output, consumption and employment although monetary policy is not following an active rule, a necessary requirement for a locally determined equilibrium in New Keynesian models with complete markets.

Comparison with Complete Markets

It is natural to ask how and when the fiscal multiplier in an incomplete markets model differs from the complete markets one. As explained above this comparison is not straightforward since, when the nominal interest rate is pegged, there is a continuum of inflation paths and fiscal multipliers if markets are complete. However, after the response of the incomplete markets model has been computed one can use the implied path of inflation rates and ask what this inflation path would imply in a model with complete markets. For example, suppose that the price level eventually returns to its pre-stimulus steady state level, $P_{ss}^{new} = P_{ss}$, so that the accumulated inflation rate equals (assuming $\pi_{ss} = 0$)

$$\prod_{t=1}^{T-1}(1+\pi_{t+1}) = \frac{P_{ss}^{new}}{P_1} = \frac{P_{ss}}{P_1} < 1, \tag{16}$$

as the price level jumps from P_{ss} to P_1 in the initial period. Then the multiplier would be smaller than one, $m < 1$, in the complete markets model. But this is not the multiplier in the model with incomplete markets as the derivation for complete markets does not apply here. Since wealth is heterogenous and credit constraints are binding occasionally, one cannot iterate using the consumption Euler equation of the representative household. Instead the stimulus policy has distributional consequences which since marginal propensities to consume are heterogenous affect aggregate consumption and thus also employment.

Distributional Consequences of a Stimulus

An increase in spending and the resulting responses of prices and hours operate through various distributional channels. 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.

This redistribution happens for two reasons. First, the demand stimulus leads to more demand for labor and thus pushes wages up but does not change income from holdings bonds, the only asset. As a result households benefit the more the more they depend on labor income to finance their consumption. The second reason is that the increase in prices lowers the real value of nominal assets. Thus, holders of nominal assets are disproportionally affected the more the more assets they hold and since labor income is not affected. Note that this last channel happens through the government budget as a lower real value of households assets

means a lower real debt burden for the government and thus higher transfers can be paid.

The redistribution of income matters since the marginal propensity to consume differs across households. In particular credit-constrained households are hand-to-mouth and have a marginal propensity of one whereas asset-rich households have a low propensity similar to a permanent-income-hypothesis household, implying an increase in demand through this redistribution. Thus this channel suggest a multiplier larger than the one implied by the accumulated inflation rate.

However, there is another, as it turns out quantitatively important, channel. The demand stimulus in combination with price stickiness implies large swings in the mark-up and thus in profits. A quantitative assessment of a fiscal stimulus therefore depends on who is the claimant of these profits and more generally on the distributional consequences of the change in profits. We assume that profits are fully taxed. Then, there are at least three possibilities how the government can use these tax receipts, corresponding to the three tax instruments available: transfers, labor subsidies and capital income subsidies. In our benchmark the taxed profits are use to pay lump-sum transfers. In another scenario the revenue from taxing profits is used to subsidize asset income which effectively makes asset holders the owner of the firms. We will also explore a subsidy to labor income, the standard assumption in new Keynesian models.

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 $G_1 = G_{ss}, G_2, \ldots, G_t, \ldots, G_{ss}$, where G_{ss} is the steady nominal spending level and $G_t \geq G_{ss}$.

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

$$m_t = \frac{\frac{Y_t P_{ss}}{P_t Y_{ss}} - 1}{\frac{G_0 P_{ss}}{P_0 G_{ss}} - 1}. \tag{17}$$

As an alternative we compare the discounted percentage change in real output to the

discounted percentage change in real government spending

$$\overline{M} = \frac{\sum_{t=0}^{\infty} \beta^t (\frac{Y_t P_{ss}}{P_t Y_{ss}} - 1)}{\sum_{t=0}^{\infty} \beta^t (\frac{G_t P_{ss}}{P_t G_{ss}} - 1)}, \tag{18}$$

where P_{ss}, G_{ss}, Y_{ss} are the steady state price level, nominal spending and nominal output respectively and $\frac{Y_t}{P_t}$ and $\frac{G_t}{P_t}$ are real output and real government spending respectively.

3.1 Calibration

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

Preferences Households have GHH preferences over labor nested within constant relative risk aversion preferences for consumption. We set the risk-aversion parameter, σ, equal to 2. We choose the discount factor, β, to target a quarterly risk-free rate of 25 BP. We assume the functional form for g:

$$g(h, s) = s\psi \frac{h^{1+\frac{1}{\varphi}}}{1 + \frac{1}{\varphi}} \tag{19}$$

This formulation implies that households do not adjust their labor supply in response to changes in their idiosyncratic productivity, but only movements in the wage rate per unit of labor efficiency. We set the Frisch elasticity, $\varphi = 0.5$, following micro estimates. We choose $\psi = 0.6$ such that in steady state $h = 1$.

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. We treat the transitory shock as measurement error. 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.

Production Technology We assume constant returns to scale so $\alpha = 1$. 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 80% of the steady state markup such that steady state profits equal 2% (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 9% of output to generate a steady-state government debt to annual GDP ratio of 0.8.

Monetary Policy For the benchmark specification we assume that the monetary authority operates a constant interest rate peg. 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:

$$i_{t+1} = \max(X_{t+1}, 0) \tag{20}$$

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.

3.2 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 ρ_g 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 three scenarios:

1. Transfer are adjusted to keep nominal debt constant.

2. Transfer are adjusted to keep real debt constant.

3. Deficit financing and later reduction of transfers to pay pack debt

For each of the three scenarios we report the dynamic response of hours, consumption, output, prices, tax revenue and debt as well as the size of the path of multipliers m_t and of the summary multiplier $\overline{M}$. In addition, we consider the case where the government pre-announces the increase in government spending. Under this scenario we assume that the government announces that the innovation to government spending will occur 12 quarters in the future.

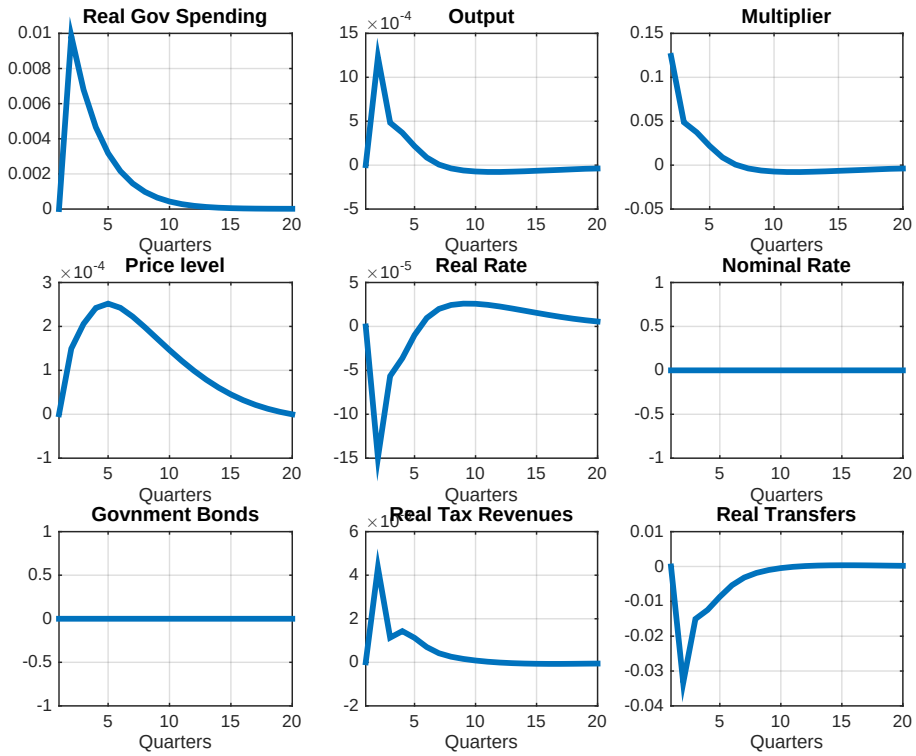
3.2.1 Transfers adjust to keep nominal debt constant

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 impulse response to a 1% innovation in government spending is plotted in Figure 1. Real government spending, the price level and output jump on impact. However, in order to keep nominal debt constant, real transfers fall about 3.5% on impact. This drop in transfers almost wholly offsets the stimulative effect from the increase in government spending. The reason is because the average MPC in the economy is around 0.35, implying that, as opposed to a representative-agent framework, the drop in transfers results in a nontrivial drop in consumption demand from households. As a result, the government spending multiplier on impact is only about 0.125. The cumulated multiplier, reported in table I, is only 0.01.

The multiplier is even smaller if the spending is pre-announced to occur at a future date. The impulse response to a spending increase 12 quarters in the future is plotted in Figure 2. The price level now increases gradually in anticipation of the future increase in government spending. On impact the multiplier is only about 0.08, again because the financing via reduction in transfers and high average MPC reduces household demand.

We find similar results if instead of an interest rate peg, the monetary authority follows a Taylor rule. The impulse responses for the Taylor rule case for this and subsequent sections

Figure 1: Impulse response to **contemporaneous** 1% increase in nominal government spending, **constant nominal debt**, and **fixed nominal rate**.

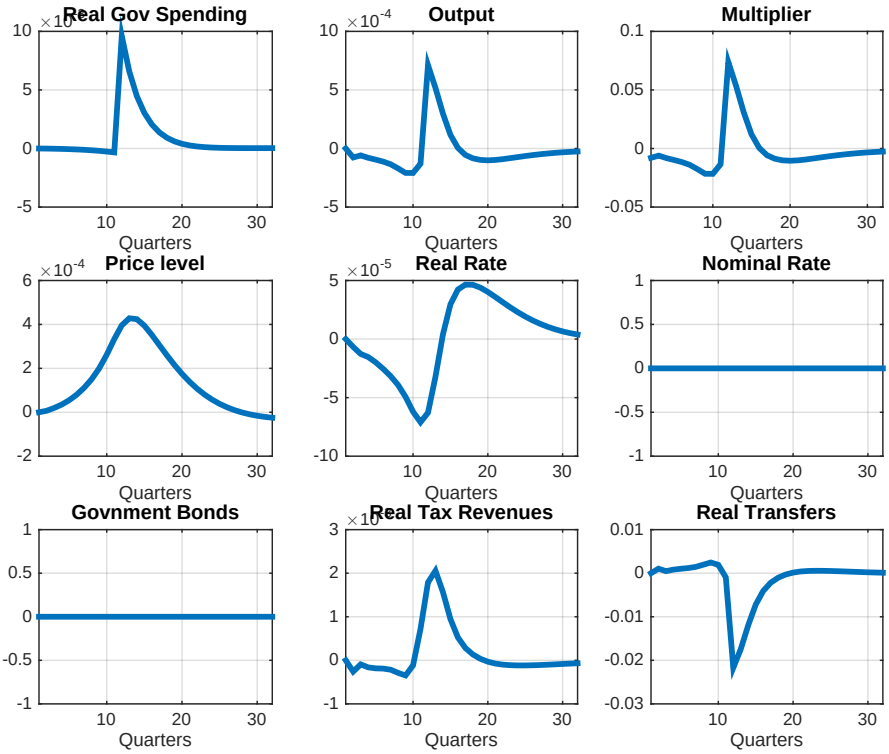


can be found in the appendix.

3.2.2 Transfers adjust to keep real debt constant

Now, we consider the same experiment, but where the government adjusts transfers in each period to keep the real value of government debt constant, as opposed to the nominal quantity of bonds considered above. The impulse response is plotted in Figure 3. This induces a larger jump in the price level on impact, which results in a larger drop in the real interest rate (since the nominal rate is fixed), resulting in a larger increase in output than in the previous exercise. However, the decrease in real transfers and high average MPC in the economy, results in a quantitatively small multiplier on impact of only about 0.2.

Figure 2: Impulse response to a **future** 1% increase in nominal government spending, **constant nominal debt**, and **fixed nominal rate**.

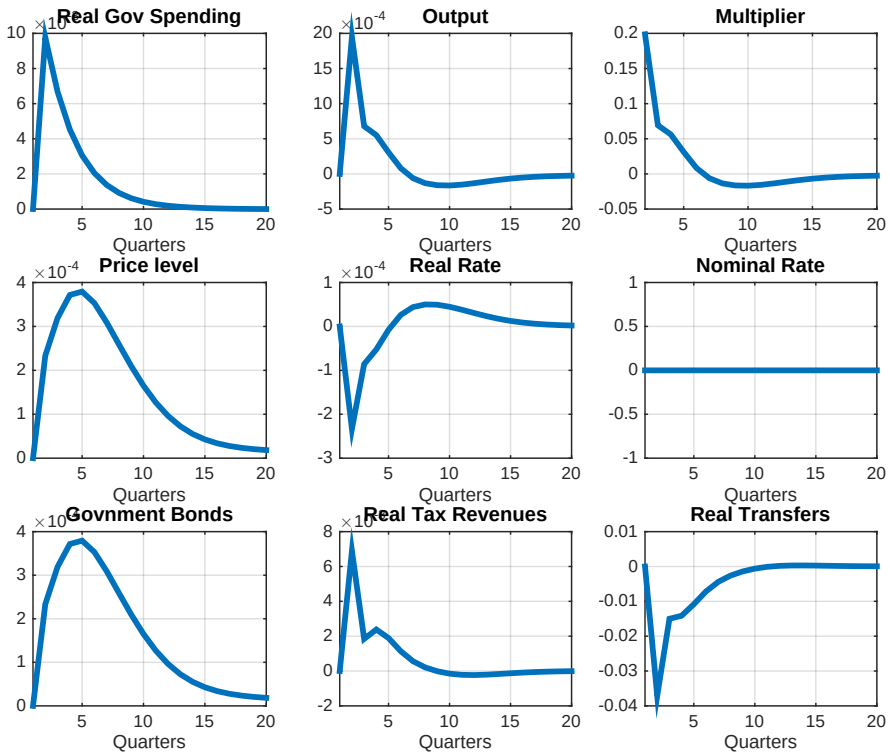


3.2.3 Deficit financing and delayed transfers pay pack debt

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 transfers to revert back to the real steady state level with autocorrelation parameter 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 impulse response is plotted in Figure 5. Note that now, as opposed to the previous experiments, real transfers are held constant for the first twenty quarters, but government debt is allowed to grow to finance the increase in government spending. This results in a significantly larger increase in the price level and output, which yields an impact multiplier of close to 3. However, the increase in government spending is ultimately financed through

Figure 3: Impulse response to **contemporaneous** 1% increase in nominal government spending, **constant real debt**, and **fixed nominal rate**.



a future reduction in transfers, which results in a contraction in output in the future. Thus, despite the large impact multiplier, the cumulated discounted multiplier is only around 0.7.

3.2.4 Transfer Multiplier

In this section we consider the multiplier in response to a one percent increase in government transfers. We assume that government spending adjusts so as 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.

The impulse reponse is plotted in Figure 7. 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

Figure 4: Impulse response to a **future** 1% increase in nominal government spending, **constant real debt**, and **fixed nominal rate**.

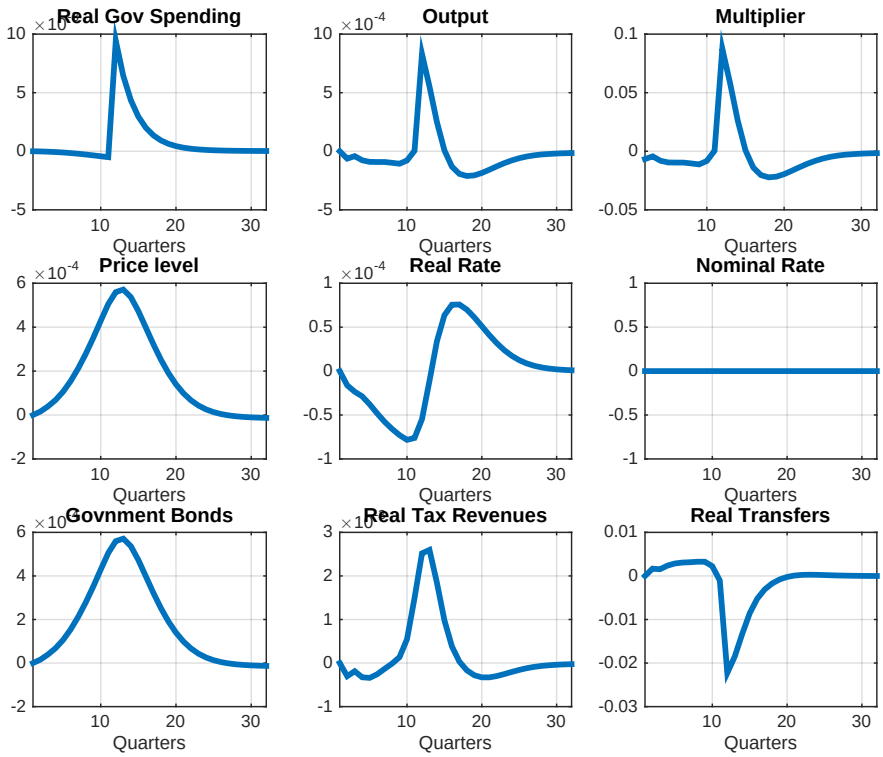
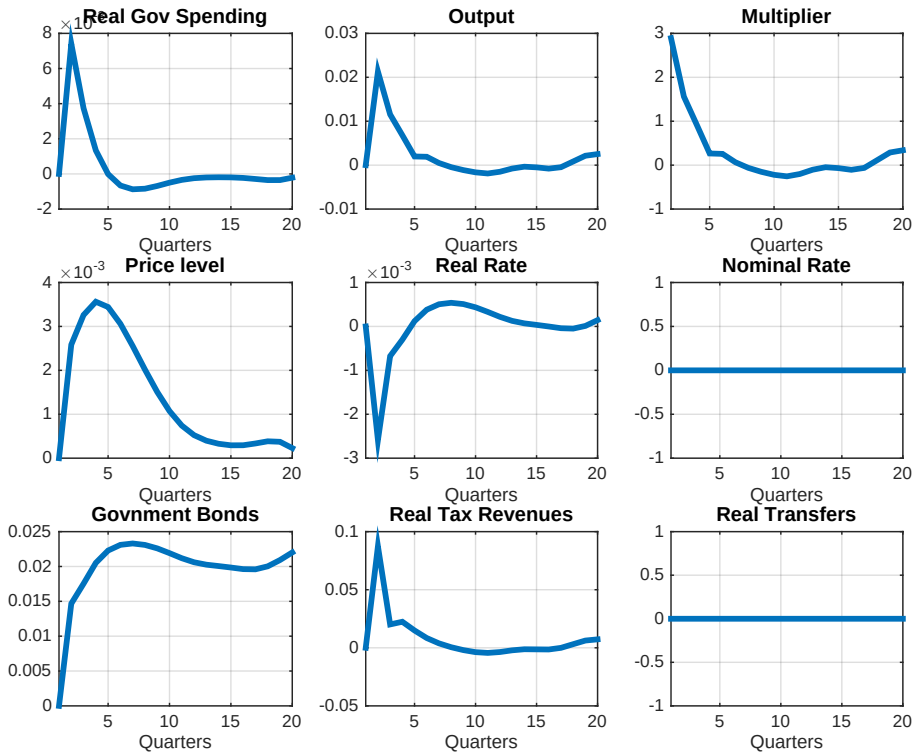


Figure 5: Impulse response to **contemporaneous** 1% increase in nominal government spending, **delayed financing**, and **fixed nominal rate**.

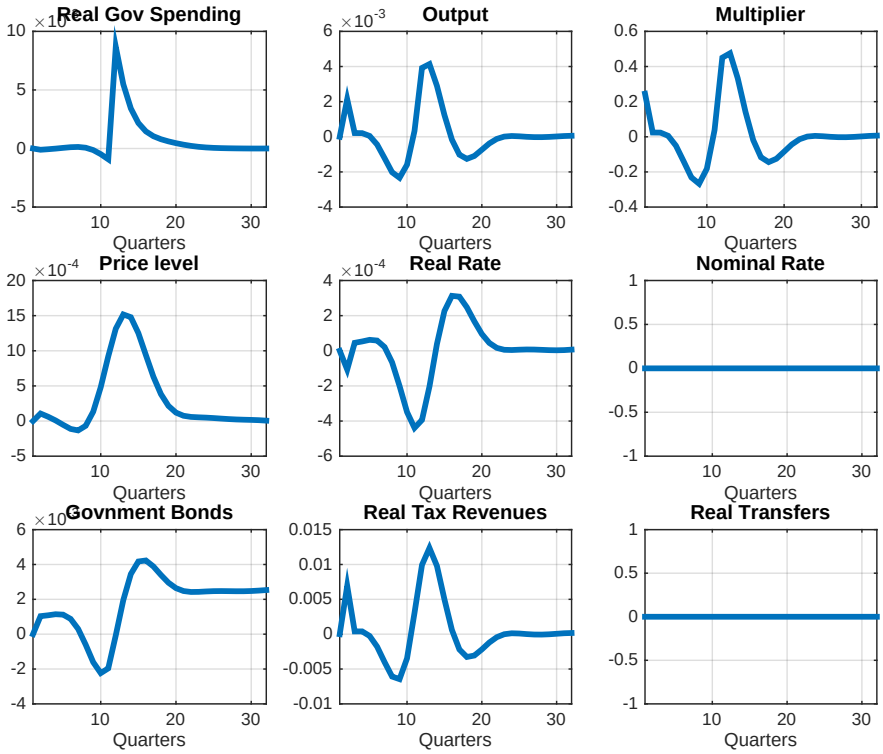


from an increase in the price level and a decline in the real rate, the heterogeneity in marginal propensities to consume means that some households will increase their spending by even more than would be implied from the fall in the real rate in a representative agent model. However, the cumulative multiplier ends up being around -0.1. As the future decrease in tranfers needed to return nominal government debt to its steady state level are sufficiently contractionary to offset the contemporaneous gains.

3.2.5 Multiplier in Response to a Demand Shock

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 assume that the discount factor of households increases from 0.992 to 0.995 for 12 quarters and then reverts for 0.992, implying that output initially drops by almost 8 percent. We solve for the impulse response to the demand shock under two scenarios

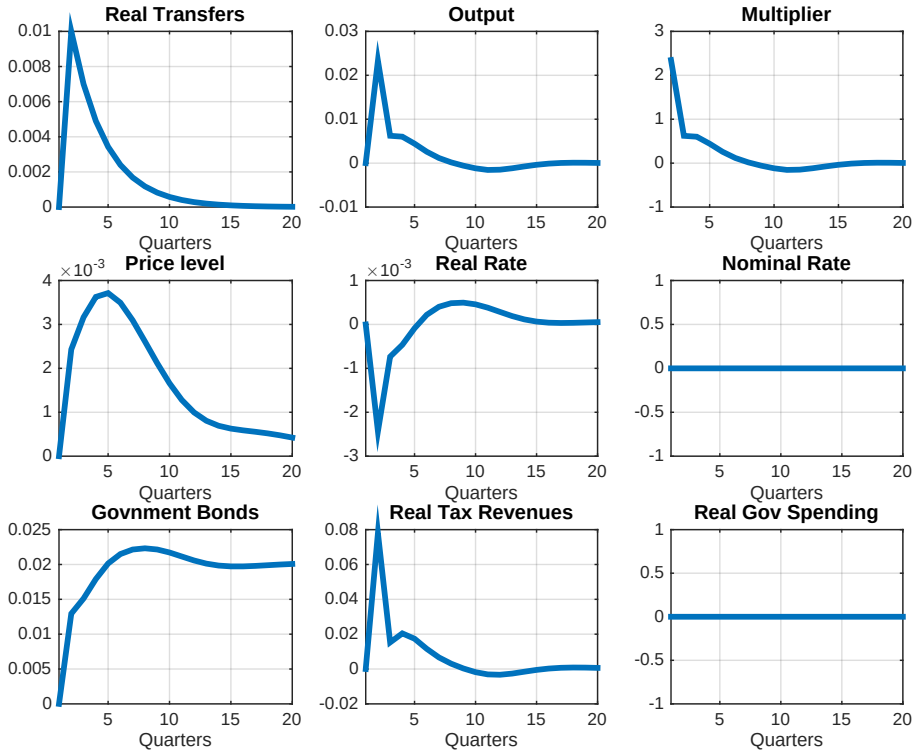
Figure 6: Impulse response to a **future** 1% increase in nominal government spending, **delayed financing**, and **fixed nominal rate**.



previously considered, one where real government debt is kept constant and the other 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 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 Figure 8. Even under this scenario, we find modest impact multipliers, siginificantly less than one.

Figure 7: Impulse response to a **contemporaneous** 1% increase in nominal transfers, **delayed financing**, and **fixed nominal rate**.



4 The Fiscal Multiplier in the Generalized Model with Capital

In this section we consider a generalized version of the model considered in the previous sections where we allow for capital accumulation (with adjustment costs and capital utilization) and for habit persistence in consumption. In addition not only prices but also wages are sticky.

4.1 The generalized Model

The government and the final good sector are as in the simple model. What changes are the household sector and the intermediate goods sector. In addition we add another sector, which transforms households savings into investment goods.

Figure 8: Impulse response to a **contemporaneous** 1% increase in nominal transfers and discount factor shock, with a **fixed nominal rate** and constant real debt (left) and delayed financing (right).

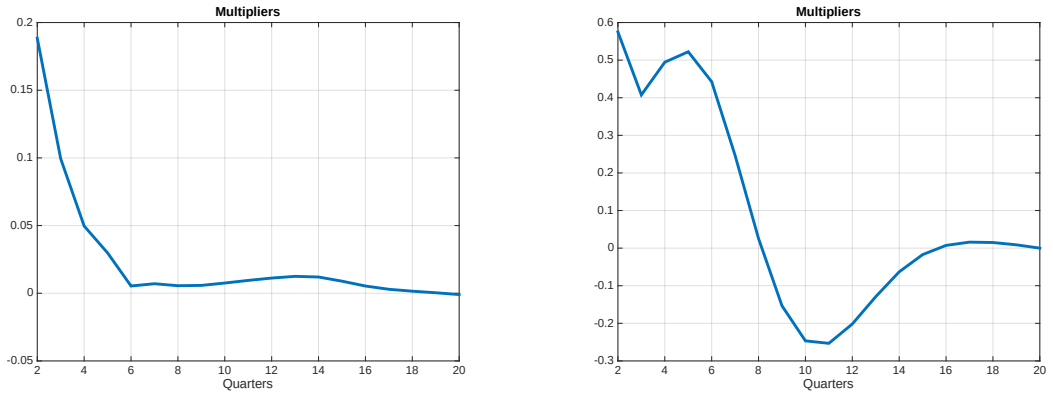


Table I: Cumulated Multiplier $\overline{M}$

	Constant Nominal Rate		Taylor Rule	
	Contemporaneous	Future	Contemporaneous	Future
Constant Nominal Debt	0.01	-0.05	0.03	0.02
Constant Real Debt	0.04	-0.06	0.04	0.01
Delayed repayment	0.70	0.05	0.57	-0.09

Note - The table contains the cumulated multiplier $\overline{M}$ for two different types of monetary policy - an interest rate peg and a Taylor rule and for three types of how the spending increase is financed - constant nominal debt, constant real debt, and deficit spending. For each of these 6 combinations of policy the Table reports results when the policy is implemented immediately and with an anticipated 12 quarter delay.

4.1.1 Households

We add habit persistence in consumption so that households utility function is

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t - \kappa c_{t-1}, h_t, s_t)$$

where:

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

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:

$$H_t = \left(\int_0^1 s_{jt} (h_{jt})^{\frac{\epsilon_w - 1}{\epsilon_w}} dj \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{21}$$

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

$$\int_0^1 W_{jt} s_{jt} h_{jt} dj, \tag{22}$$

implying a demand for the labor services of household j:

$$h_{jt} = h(W_{jt}; W_t, H_t) = \left(\frac{W_{jt}}{W_t} \right)^{-\epsilon_w} H_t, \tag{23}$$

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 $\overline{\Pi}^w$,

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

The middleman's wage setting problem is to maximize[1]

$$\begin{aligned} & V_t^w\left(\hat{W}_{t-1}\right) \\ \equiv & \max_{\hat{W}_t} \int \left(\frac{s_{jt}W_{jt}}{P_t}h(W_{jt};W_t,H_t) - s_{jt}g'(h(W_{jt};W_t,H_t))dj - \int s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t dj - Z_t\Phi_w. \\ + & \frac{1}{1+r_t}V_{t+1}^w\left(\hat{W}_t\right), \end{aligned} \tag{24}$$

where Φ_w are fixed cost of production. 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[2]

$$\theta_w\left(\pi_t^w - \overline{\Pi^w}\right)\pi_t^w = (1-\epsilon_w)w_t + \epsilon_w g''(h(\hat{W}_t;W_t,H_t)) + \frac{1}{1+r_t}\theta_w\left(\pi_{t+1}^w - \overline{\Pi^w}\right)\pi_{t+1}^w\frac{H_{t+1}}{H_t}. \tag{25}$$

The costs of wage adjustment are borne by the households directly. The remaining profits are fully taxed away by the government.

Households budget constraint equals

$$P_t c_t + b_{t+1}^h + P_t\overline{k}_{t+1}^h + P_t\Phi(\overline{k}_{t+1}^h,\overline{k}_t^h) + s_t\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t = (1+i_t)b_t^h + (1+r_t^a)P_t\overline{k}_t + (1-\tau_t)P_t w_t h_t s_t + T_t,$$

where k_t^h is the (beginning of period t) stock of physical capital with a real return r_t^a and $\Phi(k_{t+1}^h, k_t^h)$ are real portfolio adjustment costs which we specify (for now) as

$$\Phi(k_{t+1}^h, k_t^h) = \frac{\phi_k}{2}\left(\frac{k_{t+1}^h - k_t^h}{k_t^h}\right)^2 k_t^h.$$

Household supply of capital in period t is then

$$K_t^h = \int k_t^h(b,k,s_{t-1};\Omega)d\Omega_{t-1}$$

[1]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.

[2]Letting each household instead of a middleman make the wage choice would result in the same wage inflation equation if $E_t(s_{jt+1}) = s_{jt}$ what is true for a random walk but only approximately the case if the income process is highly persistent but stationary. For the middleman it is the average productivity $\int s = 1$ and not an individual s which matters and this average is time invariant, so that it drops out of the wage equation.

4.1.2 Investment-Goods Firms

The investment-good sector transforms households capital holdings into capital services $\overline{K}_t$ and sells them to the intermediate goods sector which now uses both capital and labor. Capital services, $\overline{K}_t$, are related to the physical stock of capital by $\overline{K}_t = u_t K_t$. Here, u_t denotes the utilization rate of capital and capital depreciates at rate $\delta(u)$, which we specify as

$$\delta(u) = \frac{r^k_{ss}}{1 + 1/\delta_u}(u^{1+1/\delta_u} - 1)$$

Investment-good firms engage in two activities. They rent capital K_t at a real rate $1 + r^a_t$ from householdsand choose the utilization of capital u_t and rent the resulting capital services for intermediate goods at rate $1 + r^k_t$. They also collect households investment $K^h_{t+1} - K^h_t$ and transform it into new capital K_{t+1}. Thus the investment-good firms choose K, I and u to maximize profits

$$\sum_{t=1}^{\infty} \beta^t D_t,$$

where

$$D_t = K^h_{t+1} - K^h_t + r^k_t u_t K_t - r^a_t K_t - I_t$$

and capital accumulates as

$$K_{t+1} = K_t(1 - \delta(u)) + I_t.$$

Equivalently the firm chooses the path of capital and utilization to maximize

$$\sum_{t=1}^{\infty} \beta^t \Big(K^h_{t+1} - K^h_t + r^k_t u_t K_t - r^a_t K_t - K_{t+1} + K_t(1 - \delta(u)) \Big),$$

which gives first order conditions

$$r^a_t = r^k_t u_t - \delta(u) + 1 - 1/\beta \tag{26}$$

$$r^k_t = \delta'(u). \tag{27}$$

The profits of firms in the investment goods sector are also fully taxed by the government.

Note that

$$\begin{aligned} D_t &= K^h_{t+1} - K^h_t + (\delta(u) + 1 - 1/\beta)K_t - I_t \quad (28) \\ &= K^h_{t+1} - K^h_t - (K_{t+1} - K_t) + (1 - 1/\beta)K_t, \quad (29) \end{aligned}$$

which in equilibrium equals $D_t = (1 - 1/\beta)K_t$.

4.1.3 Intermediate-Goods Firms

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

$$Y_{jt} = \begin{cases} Z_t K^{\alpha}_{jt} H^{1-\alpha}_{jt} - Z_t \Phi & \text{if} \geq 0 \\ 0 & \text{otherwise} \end{cases}, \quad (30)$$

where $0 < \alpha < 1$ and the fixed cost of production are again denoted $\Phi > 0$.

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 $mc_{jt} = \delta S_t(Y_{jt})/\delta Y_{jt}$, where

$$S_t(Y_{jt}) = \min_{K_{jt}, H_{jt}} r^k_t K_{jt} + w_t H_{jt} Y_{jt} \text{ given by (30)} \quad (31)$$

Given our functional forms, we have

$$mc_t = \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{(r^k_t)^{\alpha}(w_t)^{1-\alpha}}{Z_t} \quad (32)$$

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

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

where Φ are fixed operating costs.

The same algebra as in the simple model 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

$$d_t=Y_t-Z_t\Phi-S(Y_t)-\frac{\theta}{2}\left(\Pi_t-\overline{\Pi}\right)^2Y_t$$

Computation could be done similarly to what we do in the simple model with the modification/complication that not only prices but also a sequence of wages needs to be guessed. Form these guesses one can compute the sequence of real bond returns and the sequence of marginal costs. knowing wages and marginal costs give r^k. Using the FOC of the investment good sector gives u and r^a. One then has all the prices to compute the HH problem delivering a sequence of capital supply, bond supply and labor supply. Iterate until the bond market, capital market and the labor market clear.

4.2 Estimation

4.3 Results

5 Conclusions

[TO BE COMPLETED]

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APPENDICES

I Taylor Rule IRFs

Figure A-1: Impulse response to **contemporaneous** 1% increase in nominal government spending, **constant nominal debt**, and **Taylor rule**.

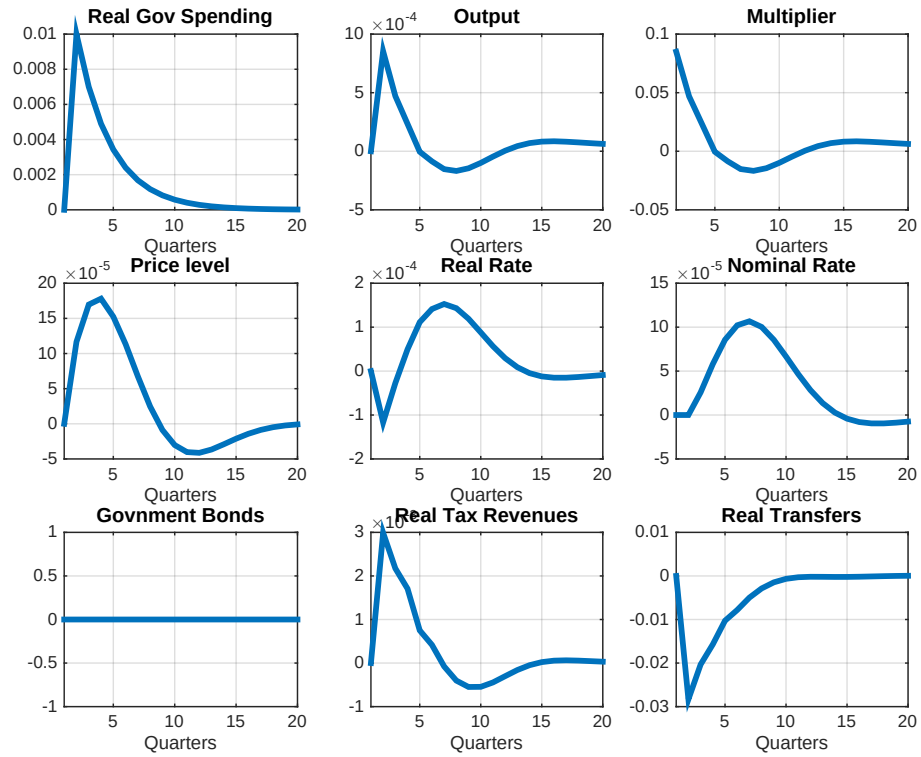


Figure A-2: Impulse response to a **future** 1% increase in nominal government spending, **constant nominal debt**, and and **Taylor rule**.

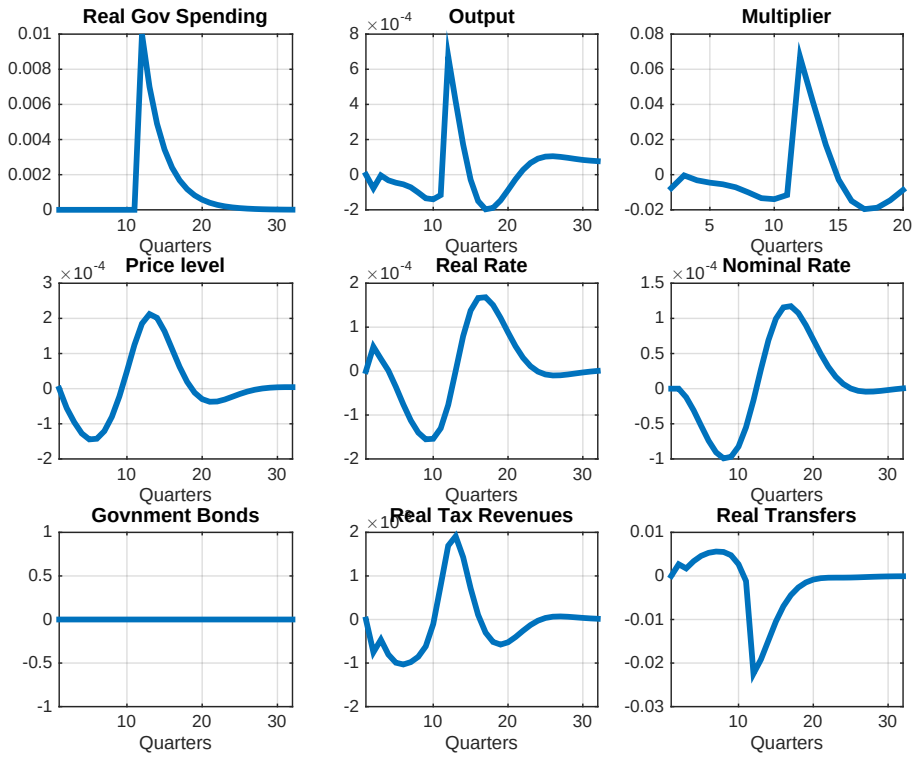


Figure A-3: Impulse response to **contemporaneous** 1% increase in nominal government spending, **constant real debt**, and **Taylor rule**.

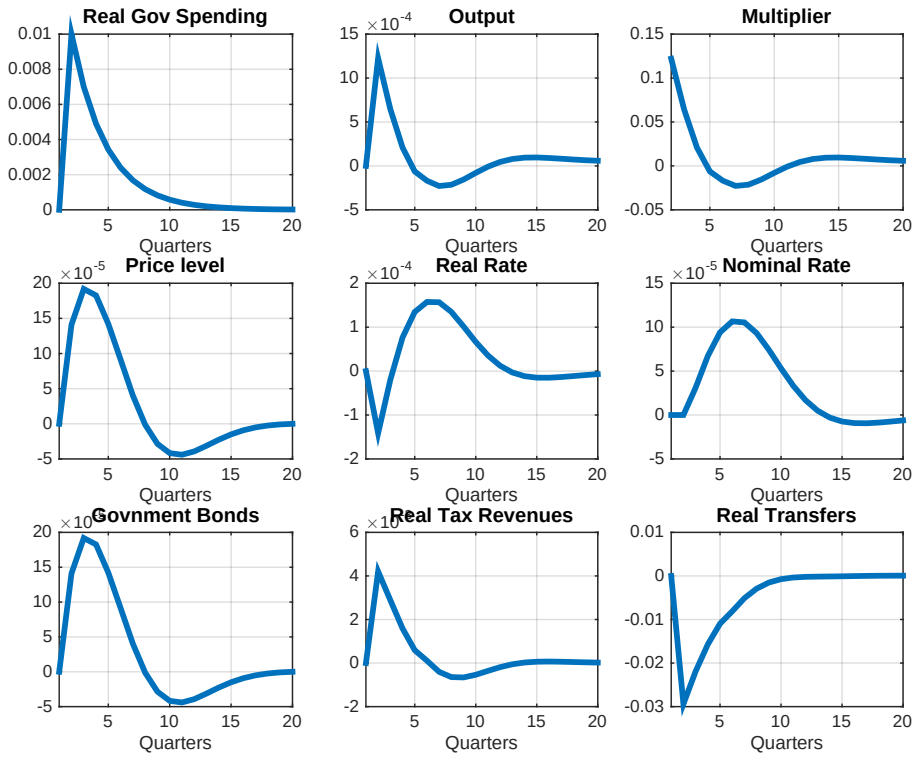


Figure A-4: Impulse response to a **future** 1% increase in nominal government spending, **constant real debt**, and **Taylor rule**.

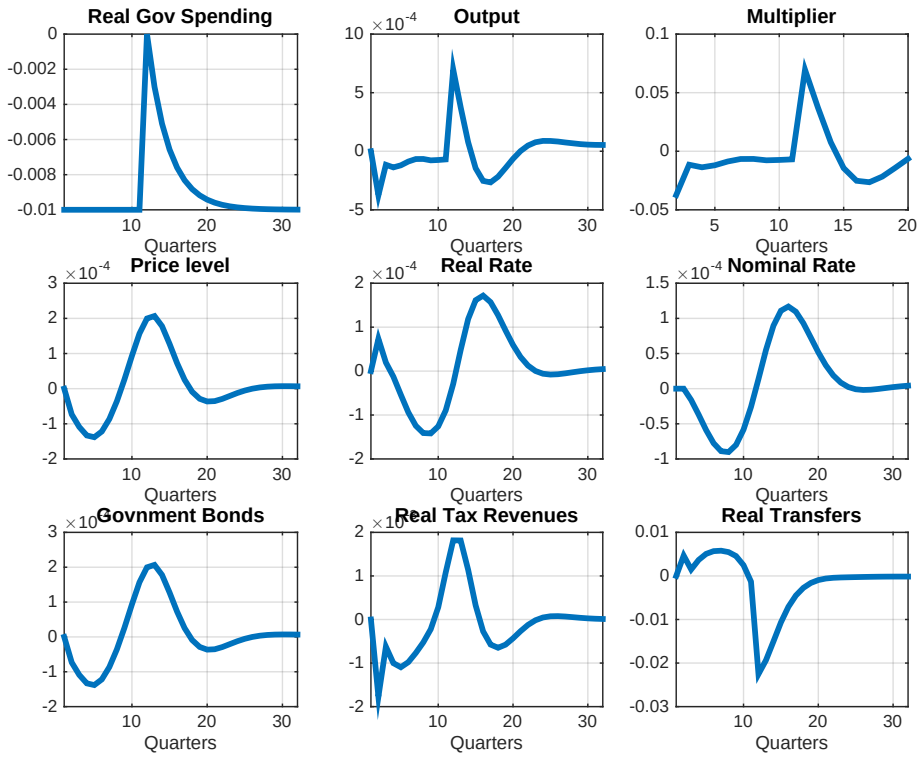


Figure A-5: Impulse response to **contemporaneous** 1% increase in nominal government spending, **delayed financing**, and **Taylor rule**.

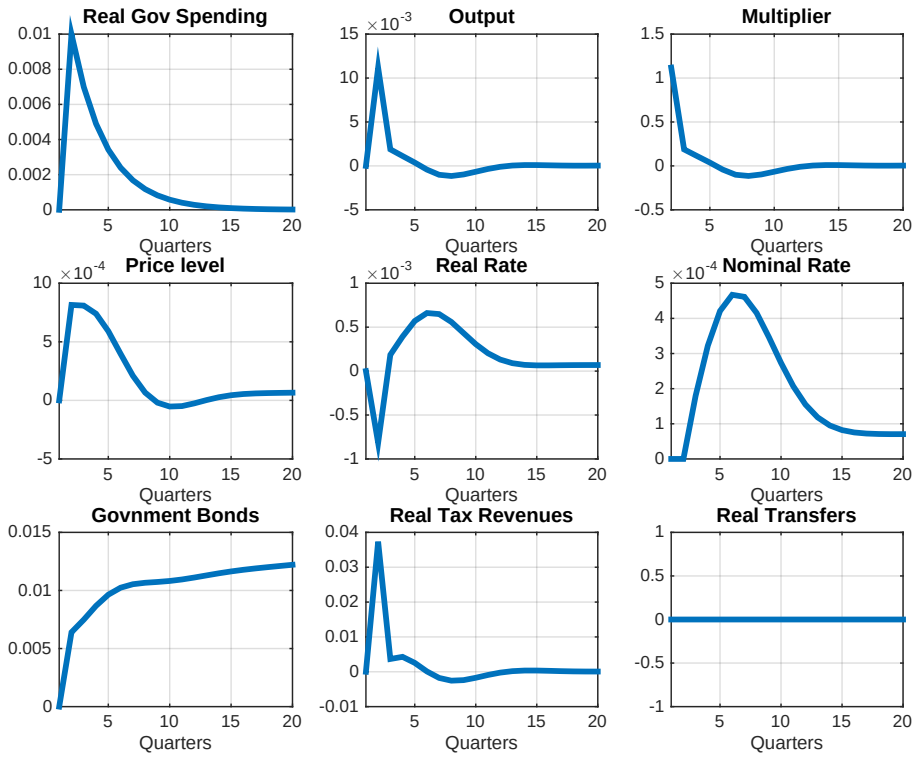
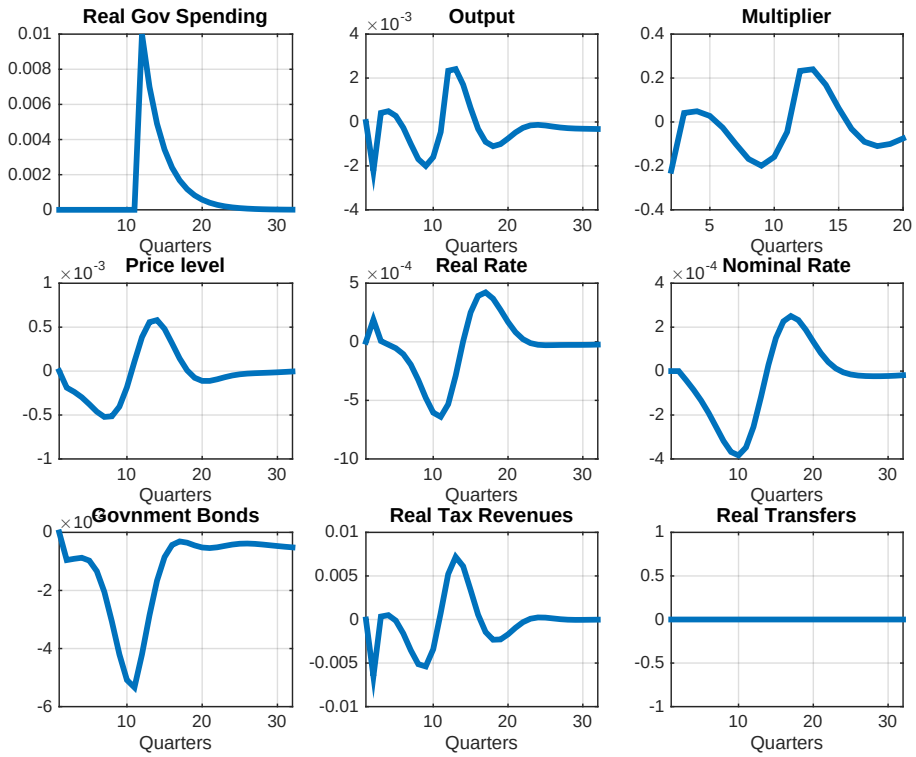


Figure A-6: Impulse response to a **future** 1% increase in nominal government spending, **delayed financing**, and **Taylor rule**.



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

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

Using that all firms choose the same price in equilibrium

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

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

$$\begin{aligned} & V_t^w\left(\hat{W}_{t-1}\right) \\ \equiv & \max_{\hat{W}_t} \int \left(\frac{s_{jt}\hat{W}_t}{P_t} h(\hat{W}_t; W_t, H_t) - s_{jt} g'(h(\hat{W}_t; W_t, H_t))dj - \int s_{jt}\frac{\theta_w}{2}\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi}^w\right)^2 H_t dj \right. \\ + & \left. \frac{1}{1+r_t} V_{t+1}^w\left(\hat{W}_t\right), \right. \end{aligned} \tag{A5}$$

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 $\hat{W}_t$

$$(1-\epsilon_w)\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w}\frac{H_t}{P_t} + \epsilon_w g''(h(\hat{W}_t; W_t, H_t))\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w-1}\frac{H_t}{W_t} - \theta_w\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi^w}\right)\frac{H_t}{\hat{W}_{t-1}} + \frac{1}{1+r_t}V'_{t+1}(\hat{W}_t) =$$

and the envelope condition

$$V'_{t+1} = \theta_w\left(\frac{\hat{W}_{t+1}}{\hat{W}_t} - \overline{\Pi^w}\right)\frac{\hat{W}_{t+1}}{\hat{W}_t}\frac{H_{t+1}}{\hat{W}_t}, \tag{A7}$$

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

Combining the FOC and and the envelope condition

$$\begin{aligned} & (1-\epsilon_w)\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w}\frac{H_t}{P_t} + \epsilon_w g''(h(\hat{W}_t; W_t, H_t))\left(\frac{\hat{W}_t}{W_t}\right)^{-\epsilon_w-1}\frac{H_t}{W_t} \\ - & \theta_w\left(\frac{\hat{W}_t}{\hat{W}_{t-1}} - \overline{\Pi^w}\right)\frac{H_t}{\hat{W}_{t-1}} + \frac{1}{1+r_t}\theta_w\left(\frac{\hat{W}_{t+1}}{\hat{W}_t} - \overline{\Pi^w}\right)\frac{\hat{W}_{t+1}}{\hat{W}_t}\frac{H_{t+1}}{\hat{W}_t} = 0 \end{aligned} \tag{A8}$$

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 $h_{jt} = H_t$:

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