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

JEL codes:

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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 will be the first to quantify the size of the fiscal multiplier in the presence of significant household heterogeneity and a uniquely determined pricel level. Further, using an incomplete markets model also allows for 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 potentially 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.

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 $\pi(s'|s)$. Agents rent their labor services, ls, 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 $(1+r) = \frac{(1+i)P}{P'}$.

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 $\Omega(a,s)$ is the distribution of agents across asset holdings and labor endowment realizations, which will determine the 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:

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

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:

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

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_t^g, a value function $v : Z \times \mathcal{M} \to \mathcal{R}$, policy functions $a' : Z \times \mathcal{M} \to \mathcal{R}_+$ and $c : Z \times \mathcal{M} \to \mathcal{R}_+, h : Z \times \mathcal{M} \to \mathcal{R}_+$, $H : A \to \mathcal{R}_+$, pricing functions $r : A \to \mathcal{R}$ and $w : A \to \mathcal{R}_+$, and law of motion $\Gamma : A \to A$, such that:

1. v satisfies the Bellman equation, and a', c, h are the policy functions, given $r(), w()$

2. w and $h()$ satisfy:

$$w(\Omega)s(1-\tau_t) = g'(h(s,...))$$

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

$$\begin{aligned} B' &= \int a'(a,s;\Omega)d\Omega \\ H(\Omega) &= \int shd\Omega \\ Y_t = Z_t H_t^{1-\alpha} &= \int c(a,s;\Omega)d\Omega + \frac{G}{P} + \Phi + \frac{\theta}{2}\left(\Pi_t - \overline{\Pi}\right)^2 Y_t \end{aligned}$$

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

3 The Fiscal Multiplier

In this Section 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

$$m_t = \frac{\frac{Y_t P_{ss}}{P_t Y_{ss}} - 1}{\frac{G_0 P_{ss}}{P_0 G_{ss}} - 1}. \tag{8}$$

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

$$\overline{M} = \frac{\sum_{t=0}^{\infty} \beta^t (\frac{Y_t P_{ss}}{P_t Y_{ss}} - 1)}{\sum_{t=0}^{\infty} \beta^t (\frac{G_t P_{ss}}{P_t G_{ss}} - 1)}, \tag{9}$$

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:

$$g(h, s) = s\psi \frac{h^{1+\frac{1}{\varphi}}}{1 + \frac{1}{\varphi}} \tag{10}$$

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)).[1]

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:

$$i_{t+1} = \max(X_{t+1}, 0) \tag{11}$$

where

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

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.

[1]These small profits are fully taxed. In the benchmark these are distributed to households as lump-sum transfers. As we will show, how the government redistributes additional revenue affects the response of the economy quite a bit. We therefore will also explore different scenarios. In one 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.

3.2 Results

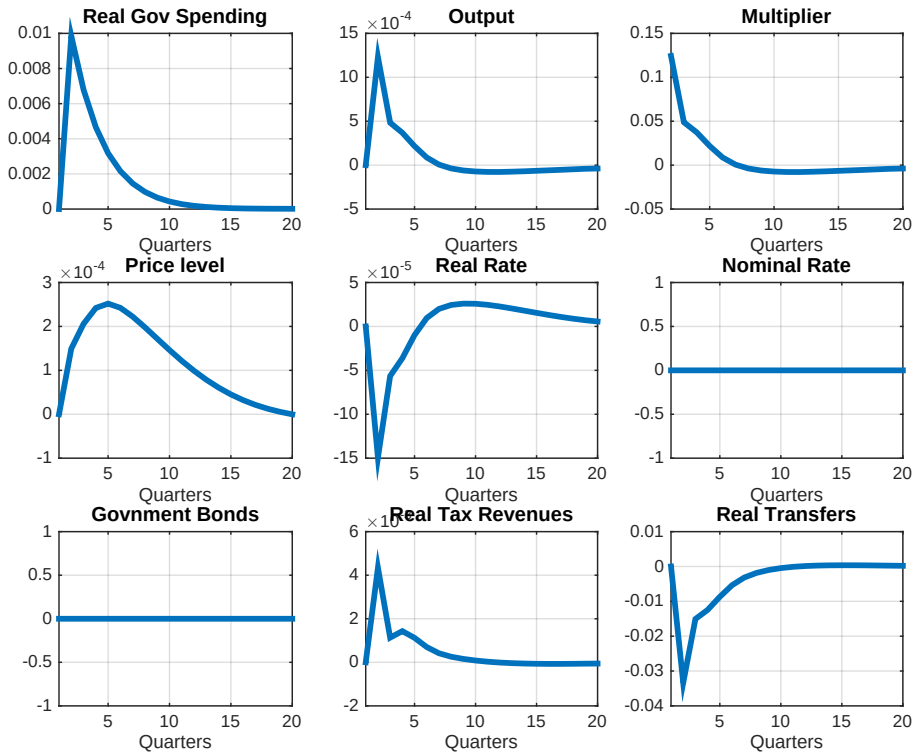
We can now compute the response of prices, employment, output and consumption to a persistent increase in nominal government consumption by one percent where spending follows an AR(1) process with parameter ρ_g after the initial innovation. Balancing the government budget when government spending is 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. For each of the four 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.

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

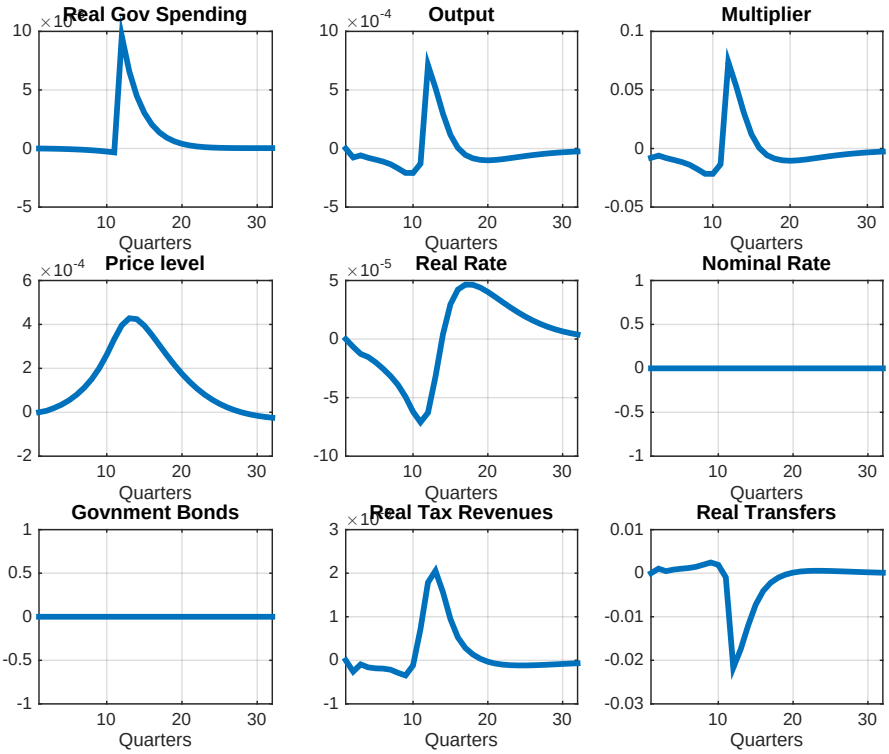


We find similar results if instead of an interest rate peg, the monetary authority follows a Taylor rule. The impulse responses for the Taylor rule case for this and subsequent sections can be found in the appendix.

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**.

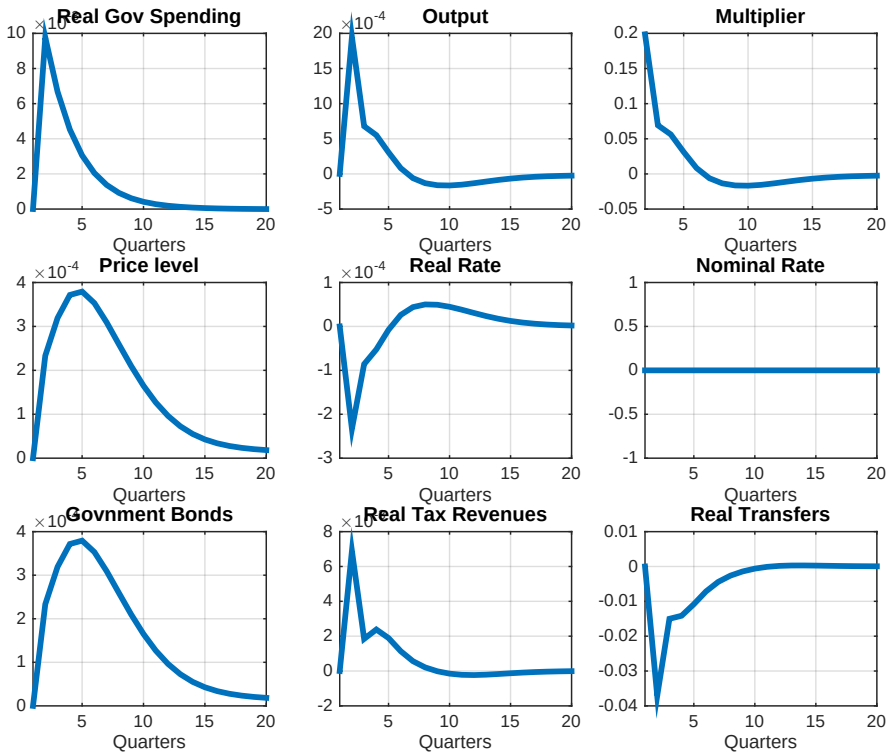


3.2.3 Delayed transfers to return to same value of debt

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.

4 A Full Model with Capital

[TO BE COMPLETED]

5 Conclusions

[TO BE COMPLETED]

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

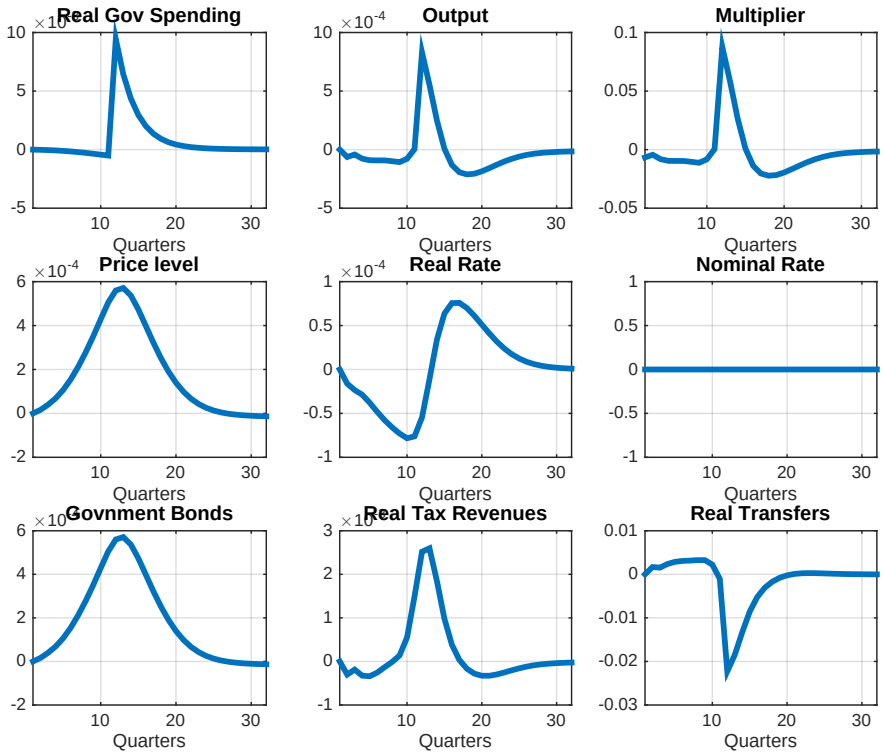


Table I: Cumulated Multiplier $\overline{M}$

	Constant Nominal Rate		Taylor Rule	
	Contemporaneous	Future	Contemporaneous	Future
Constant Nominal Debt	0.01	-0.05	0.03	-0.05
Constant Real Debt	0.04	-0.06	0.04	-0.05
Delayed repayment	0.70	0.05	2.87	-0.03

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.

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

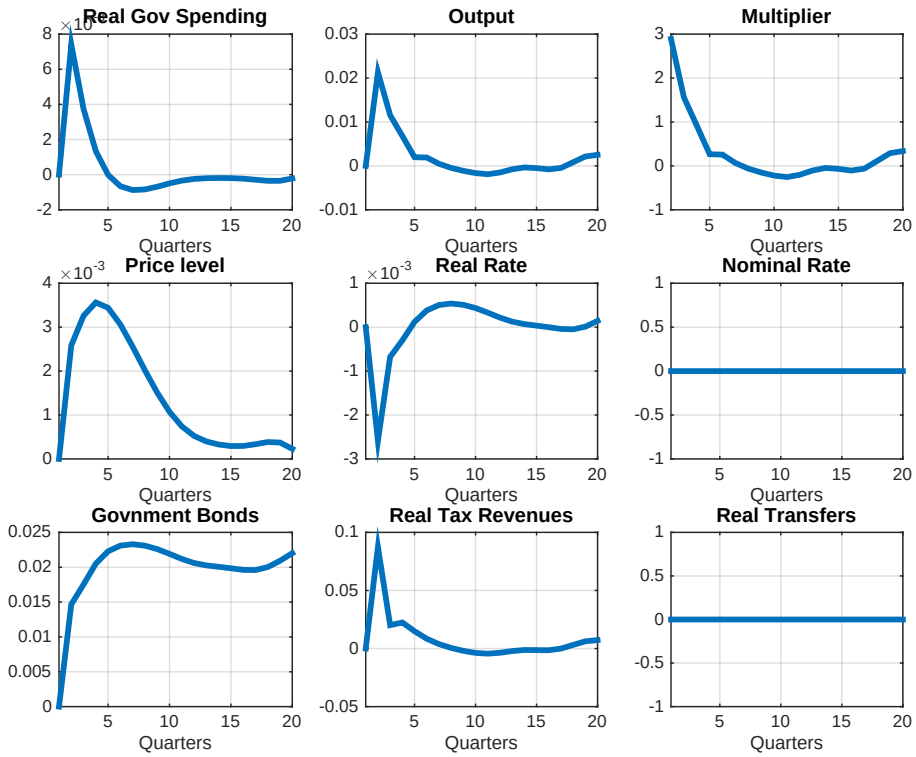
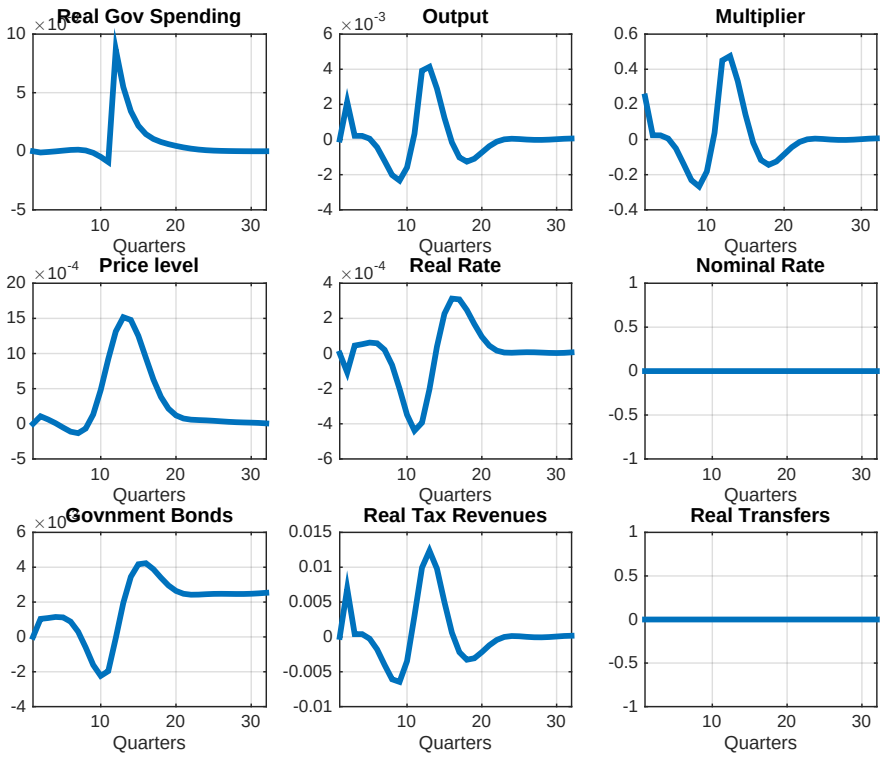


Figure 6: Impulse response to a **future** 1% increase in nominal government spending, **delayed financing**, and **fixed nominal rate**.



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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**.

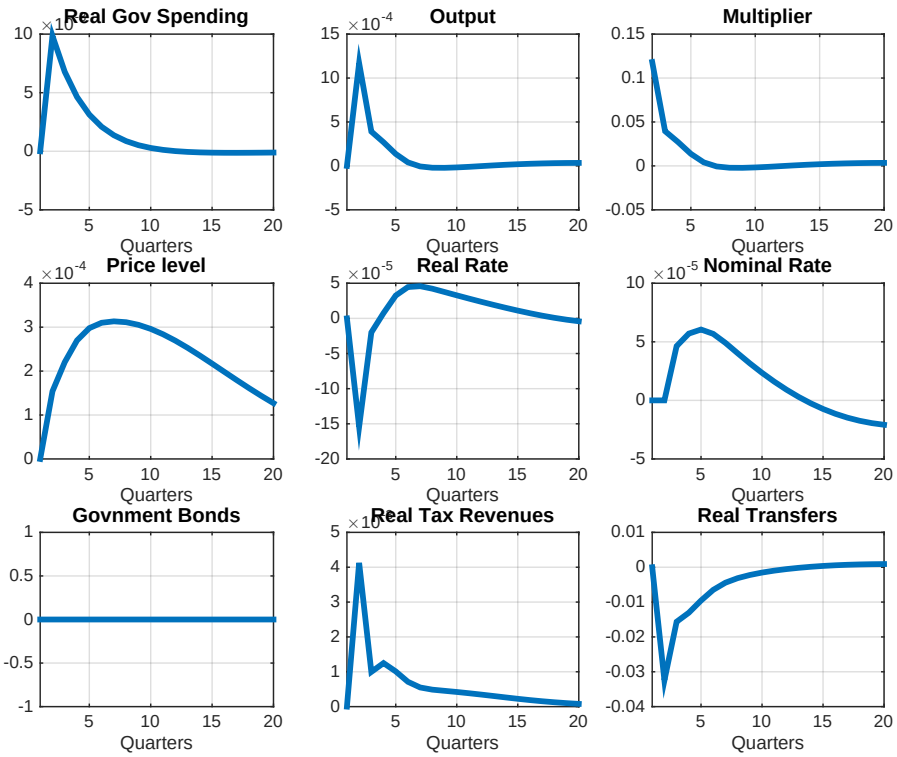


Figure A-2: Impulse response to a **future** 1% increase in nominal government spending, **constant nominal debt**, and and **Taylor rule**.

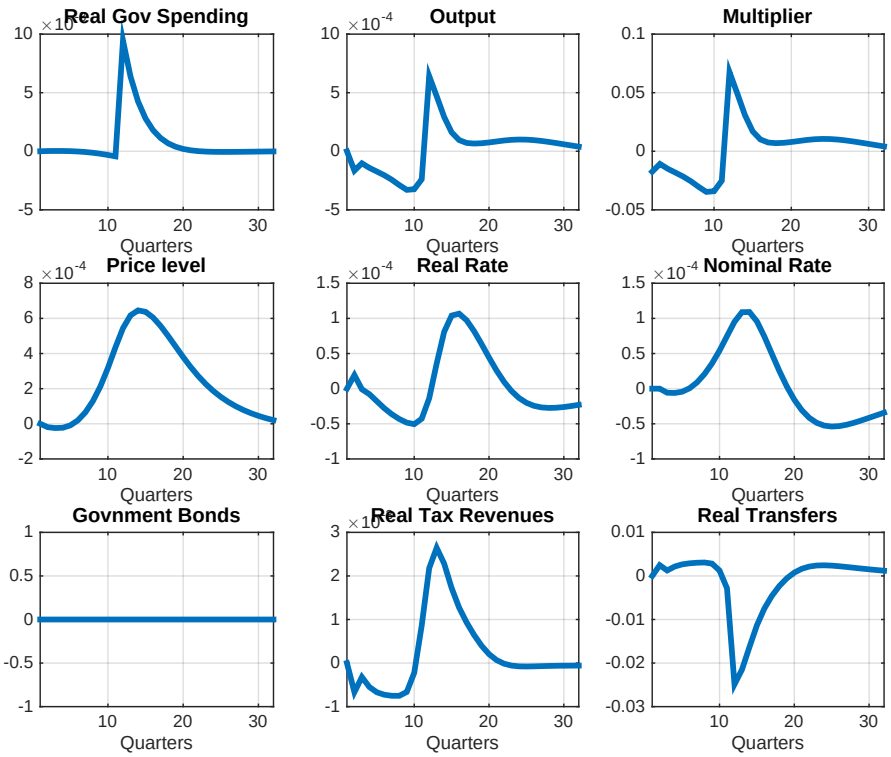


Figure A-3: Impulse response to **contemporaneous** 1% increase in nominal government spending, **constant real debt**, and **Taylor rule**.

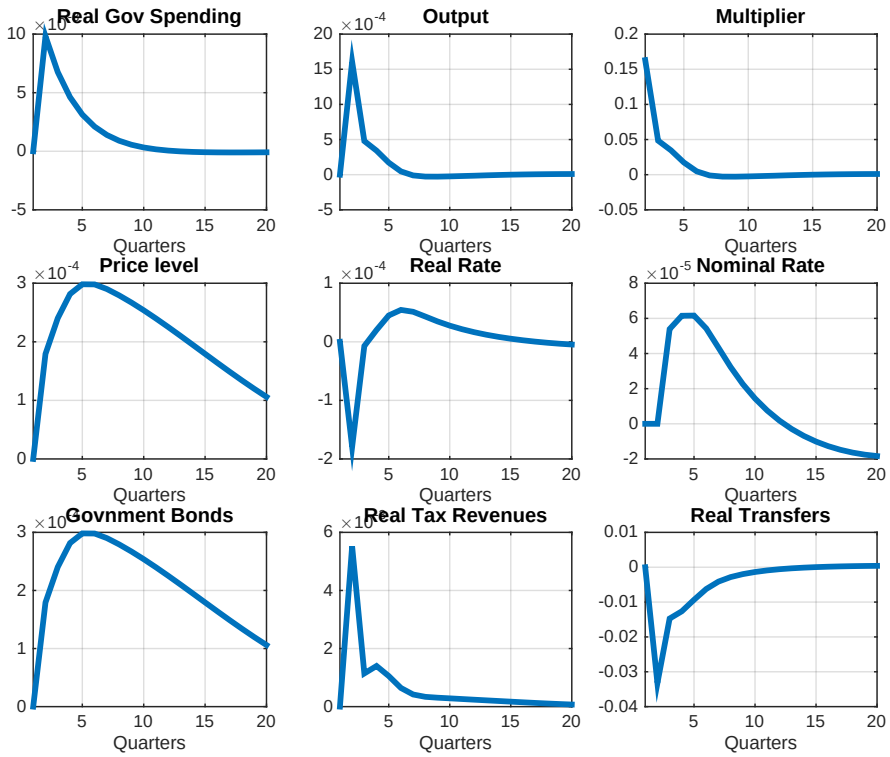


Figure A-4: Impulse response to a **future** 1% increase in nominal government spending, **constant real debt**, and **Taylor rule**.

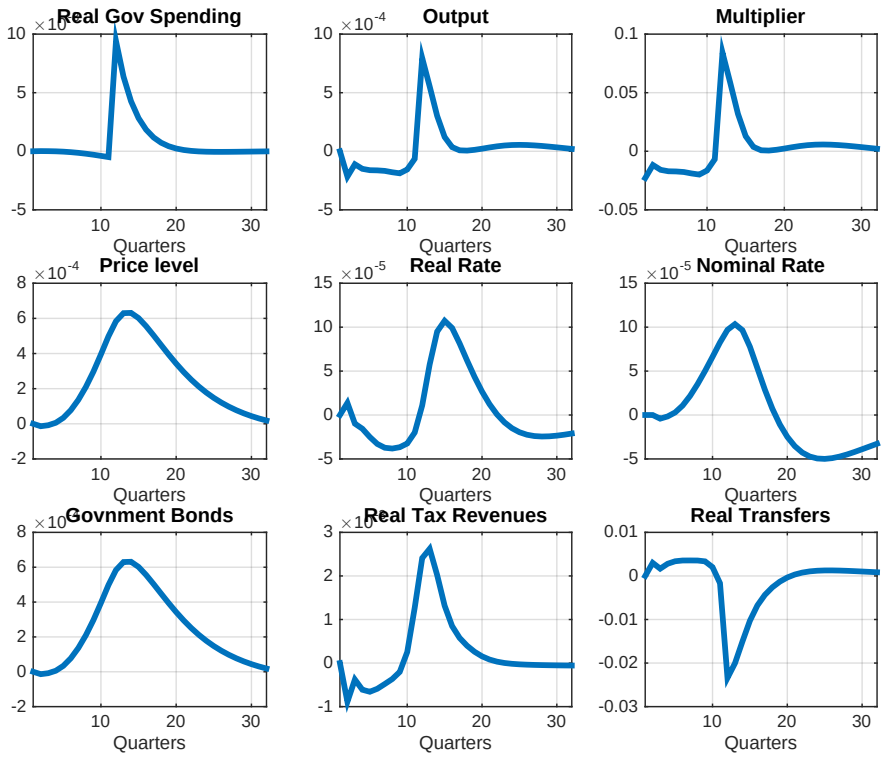


Figure A-5: Impulse response to **contemporaneous** 1% increase in nominal government spending, **delayed financing**, and **Taylor rule**.

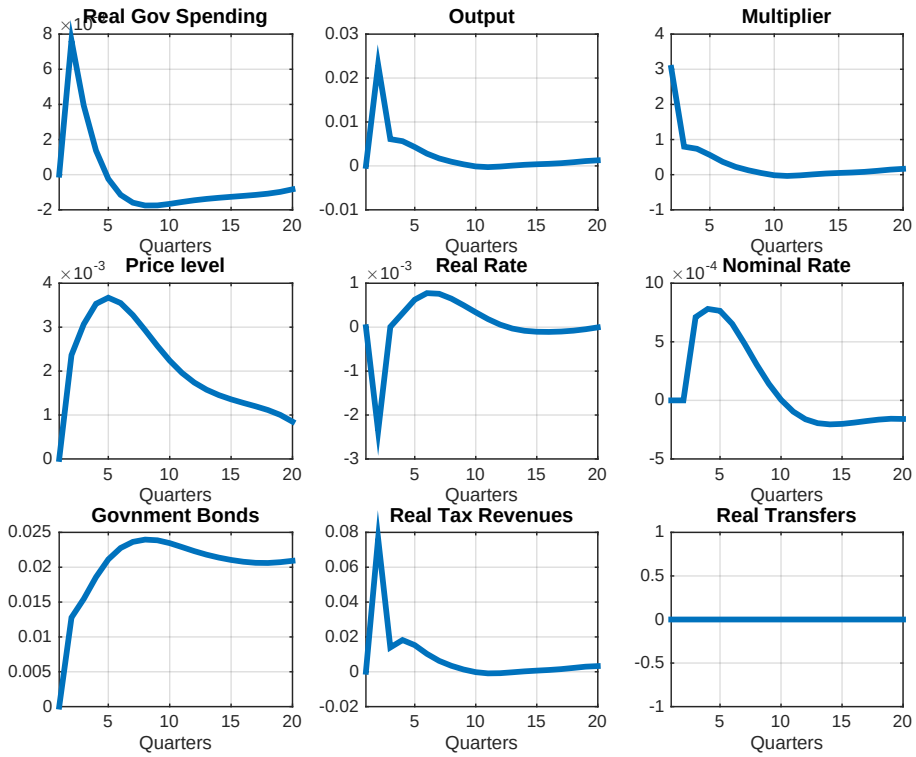
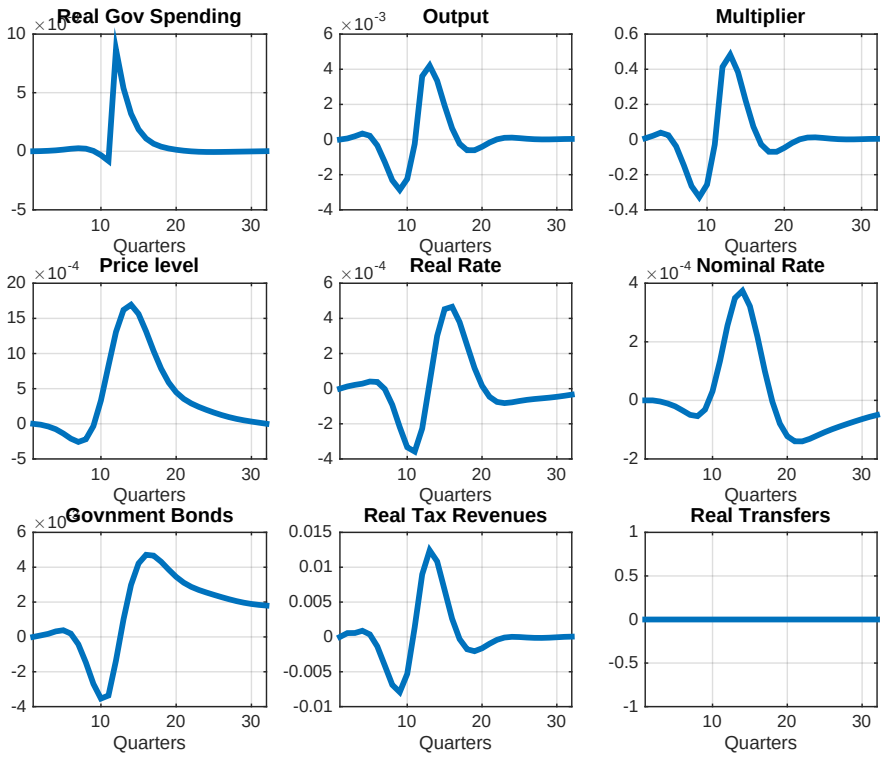


Figure A-6: Impulse response to a **future** 1% increase in nominal government spending, **delayed financing**, and **Taylor rule**.



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

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