FISCAL STIMULUS UNDER AVERAGE INFLATION TARGETING

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Abstract. We study the effectiveness of fiscal stimulus under average inflation targeting (AIT)—a new monetary policy framework that the Federal Reserve has recently adopted—in a New Keynesian model featuring interactions between monetary policy and fiscal policy. AIT implies gradual adjustments in the policy interest rate that reacts to a history-dependent inflation target. In a monetary regime with active monetary rule and passive fiscal rule, government spending raises inflation on impact, reducing the real interest rate and boosting aggregate demand. Over time, however, monetary policy tightening is required to reduce inflation and keep average inflation at target. Thus, the real interest rate rises in future periods, crowding out private consumption, rendering the cumulative fiscal multiplier smaller than the impact multiplier. In a fiscal regime with an active fiscal rule and a passive monetary rule, an expansionary fiscal policy shock pushes up inflation persistently, with no inflation makeup because of weak reactions of monetary policy to average inflation. Thus, the real interest rate stays below steady state persistently, resulting in a larger cumulative multiplier than the impact multiplier. In a liquidity trap driven by a negative demand shock, increasing history-dependence of the inflation target shortens the duration of the liquidity trap. Since the interest rate stays at the zero lower bound (ZLB), a government spending shock that raises inflation would reduce the real interest rate, resulting in a fiscal multiplier that is larger than that in normal times. Under the monetary regime, however, greater history-dependence of the inflation target leads to a smaller fiscal multiplier because higher inflation now needs to be compensated by lower inflation later. Under a fiscal regime, there is no inflation makeup and the history-dependence of the inflation target has a nonlinear effect on the size of the government spending multipliers in a liquidity trap.

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I. Introduction

In response to the recent COVID-19 pandemic, many countries have implemented aggressive monetary and fiscal policy measures to cushion the economic fallout from the pandemic-induced recession. In March 2020, the Federal Reserve cut the federal funds rate to zero and implemented large-scale asset purchasing programs to support the functioning of the financial markets and the economy. Since the onset of the pandemic, the US Congress has also passed several rounds of large-scale fiscal stimulus programs, including the $2.2 trillion Coronavirus Aid, Relief, and Economic Security Act of March 2020, the $900 billion coronavirus relief and government funding bill of December 2020, and the $1.9 trillion American Rescue Plan of March 2021. The scale and the scope of these policy interventions are unprecedented in the post World War II periods.

Evaluating the effectiveness of these policy interventions requires a theoretical framework that takes into account interactions between monetary policy and fiscal policy. For example, when monetary policy is constrained by the zero lower bound (ZLB), government spending would have a much larger stimulus effects than when monetary policy is unconstrained. In an economy with forward-looking agents, what monetary policy does in normal times when it is unconstrained can also affect the effectiveness of fiscal policy during the ZLB periods. Thus, changes in monetary policy framework can have important implications for fiscal stimulus.

One important change in the Federal Reserve's monetary policy framework is the switch from the standard inflation targeting policy to average inflation targeting (AIT) that occurred in August 2020. Under AIT, monetary policy allows inflation to overshoot the target level for some periods if inflation has fallen below the target in the past, such that the inflation rate is, on average, close to the targeted level.

Recent studies focus on the implications of AIT for the effectiveness of monetary policy in macroeconomic stabilization. It has been shown that AIT is more effective than the standard inflation targeting policy for attenuating shortfalls in the output gap in an economy where the zero lower bound (ZLB) occasionally constrains the ability of monetary policy to offset negative demand shocks (Mertens and Williams, 2019, 2020). In the standard New Keynesian models, AIT with sufficiently long history-dependence approximates price-level targeting and improves welfare relative to standard inflation targeting (Budianto et al., 2020; Amano et al., 2020).

Much less is known about the implications of AIT for the effectiveness of fiscal policy in stabilizing macroeconomic fluctuations. This paper studies the effectiveness of fiscal stimulus under AIT in a New Keynesian model featuring interactions between fiscal policy and monetary policy, both in normal times when monetary policy is unconstrained and in a liquidity trap with binding ZLB constraints.

Our model builds on the standard New Keynesian framework (Woodford, 2003), featuring a monetary policy rule and a fiscal policy rule in the spirit of Leeper (1991) and Davig and Leeper (2011), with occasionally binding ZLB. We introduce AIT in the monetary policy rule, under which the short-term nominal interest rate reacts to an inflation target that is a moving average of past inflation rates (Budianto et al., 2020). Using this simple theoretical framework, we examine how the history-dependence of the inflation target affects the fiscal multipliers under alternative policy regimes, both in normal times and in a liquidity trap with a binding ZLB constraint.

We consider two different policy regimes, a monetary regime and a fiscal regime. Under the monetary regime (M), the central bank pursues an active monetary policy by following the Taylor principle; at the same time, the fiscal authority raises lump-sum taxes sufficiently to finance increases in government spending, such that the Ricardian equivalence holds (Galí et al., 2007; Galí, 2020). The fiscal regime (F), in contrast, features passive monetary policy and active fiscal policy. Under this regime, an increase in government spending is not financed by an equivalent increase in future lump-sum taxes, and monetary policy does not raise the nominal interest rate aggressively to stabilize inflation (Woodford, 1998; Kim, 2003; Davig and Leeper, 2011). Through both analytical results and numerical simulations, we show that the stimulus effects of fiscal policy expansions crucially depend on the extent of history-dependence of the AIT (denoted by ρ).

In regime M, a temporary increase in government spending raises aggregate output and inflation. Under the standard inflation-targeting policy, monetary policy responds to the increase in inflation aggressively, resulting in an increase in the real interest rate that crowds out private consumption spending through intertemporal substitution. The increase in government spending will be financed by equivalent increases in future lump-sum taxes, creating a negative wealth effect that further crowds out private consumption. The decline in private consumption dampens the stimulus effect of government spending on aggregate output, leading to a fiscal multiplier that is less than one (Galí et al., 2007).

Under AIT, monetary policy responds to average inflation in the current and past periods. Since average inflation rises slowly following the government spending shock, the nominal interest rate also adjusts slowly, dampening the rise in the real interest rate. The stronger the history dependence of the AIT rule, the slower the adjustments in the nominal interest rate and the smaller the increase in the real interest rate, mitigating the crowd-out effects on private consumption. As a consequence, the impact multiplier of government spending (i.e., the percent increases in aggregate output in the impact period of the government spending shock) increases with ρ.

Overtime, however, the initial rise in inflation needs to be compensated by subsequent declines, such that average inflation remains at the target level (Mertens and Williams, 2019). This "makeup" feature of AIT implies that the real interest rate would stay above steady state for longer periods than under the standard Taylor rule, resulting in more persistent crowding out of private consumption following the government spending shock. As a consequence, the cumulative multiplier of government spending (i.e., the cumulative percent increases in aggregate output for one-period cumulative increases in government spending) decreases with ρ.

In regime F, an increase in government spending is not associated with sufficient increases in future lump-sum taxes to repay the public debt. With smaller tax hikes expected, the household perceives the newly-issued government debt as an increase in nominal wealth, boosting consumption demand, reinforcing the positive effects of the government spending shock on aggregate demand. Higher government spending also creates higher expected inflation. Under the passive monetary policy, however, the central bank does not respond to inflation by raising the nominal interest rate aggressively, resulting in a lower real interest rate, further boosting consumption demand through intertemporal substitution. Thus, the government spending multiplier under the fiscal regime is greater than that under the monetary regime. This result can be obtained under the standard Taylor rule without consideration of AIT (Beck-Friis and Willems, 2017).

AIT has different implications for fiscal stimulus under the fiscal regime than under the monetary regime. Unlike the monetary regime, AIT under the fiscal regime does not feature an inflation makeup following an expansionary fiscal policy because passive monetary policy allows inflation to stay persistently above its steady-state level. The stronger the history-dependence of the targeted average inflation, the smaller the increases in the nominal interest rate relative to expected inflation, and the greater the declines in the real interest rate. Thus, the impact multiplier of government spending increases with ρ. Similar to the case with the monetary regime, a stronger history-dependence of the targeted inflation implies a flatter time-profile of the nominal interest rate responses to the shock. Thus, the real interest rate also stays persistently above the steady state, depressing aggregate demand in subsequent periods. As a consequence, the cumulative multiplier of government spending decreases with ρ.

We also study the implications of AIT for fiscal stimulus when monetary policy is occasionally constrained by the ZLB. We consider a sharp and persistent contraction in aggregate demand (in particular, a shock that lowers the natural real rate) that pushes the nominal rate to the ZLB, with the liftoff date from the ZLB endogenously determined. We consider the monetary regime and the fiscal regime separately.

Under the monetary regime at the ZLB, a temporary government spending shock has larger stimulus effects than in the normal periods, because the increase in expected inflation leads to a larger reduction in the real interest rate when the nominal rate stays at zero. This is true under the standard Taylor rule (Christiano et al., 2011; Eggertsson, 2011); and it also true under the AIT rule.[1]

An increase in history dependence under AIT, however, reduces the government spending multipliers at the ZLB because of the makeup feature of AIT. During the ZLB periods, inflation increases following a government spending shock. When the economy eventually exits from the ZLB, monetary policy tightening is required to reduce inflation to keep average inflation at the target level. The greater the history dependence of the inflation target, the stronger the makeup effects. A decline in expected inflation reduces current inflation while the economy is still in the ZLB, weakening the stimulus effects of government spending. With sufficiently strong history dependence, however, the economy would never enter the ZLB, such that the fiscal multipliers coincide with those in the normal times with unconstrained monetary policy.

Under the fiscal regime at the ZLB, an increase in government spending acts like a debt-financed tax cut, increasing the household's perceived wealth and boosting private consumption. The increase in aggregate demand raises inflation, lowering the real interest rate and further boosting consumption through intertemporal substitution. With the nominal rate remaining at zero, the increase in inflation reduces the real rate in the ZLB periods more than it does in normal times, implying larger government spending multipliers at the ZLB than in normal times. Furthermore, under the fiscal regime, the wealth effect and the intertemporal substitution effect both raise private consumption, resulting in a government spending multiplier larger than that under the monetary regime.

Under the fiscal regime, AIT has important implications for fiscal stimulus at the ZLB. Agents expect that, after liftoff from the ZLB, passive monetary policy would allow inflation to stay above steady state, despite that the government spending shock raises inflation at the ZLB. Stronger history dependence of AIT (i.e., a larger ρ) implies that the nominal interest rate will stay lower for longer after liftoff from the ZLB, allowing inflation to stay above steady state for longer. Although the increase in current inflation at the ZLB boosts aggregate demand through intertemporal substitution, the increases in future inflation outside of ZLB erode the value of nominal wealth associated with the debt-financed tax cut, lowering

[1]For empirical evidence that the government spending multiplier is larger in the ZLB periods than in normal times, see, for example, Miyamoto et al. (2018) and Ramey and Zubairy (2018). For a survey of the empirical literature, see Ramey (2019).

the impact multiplier of government spending at the ZLB. These two opposing forces associated with AIT renders the relation between government spending multiplier and the history dependence of AIT nonlinear. With small values of ρ, the impact multiplier increases with ρ; with large values of ρ, the impact multiplier decreases with ρ. If ρ is sufficiently large, then the economy would never enter the ZLB, such that the government spending multiplier coincides with that in normal times.

II. Related literature

III. Model

We consider a basic cashless new Keyneisan model augmented with a government sector. The government levies lump-sum taxes and issues one-period nominal riskless bonds to finance exogenous government spending. The model is fairly standard and can be found in the textbooks of Woodford (2003) and Gali (2005). The only new element is that we replace the usual inflation targeting rule with the AIT rule. In Section 2.1 we present the log-linearized equilibrium system directly and discuss its microfoundation in Appendix A. In Section 3.3 we provide a baseline calibration for all numerical results in the paper. In Section 3.3 we define fiscal multipliers.

III.1. **Log-linearized Equilibrium System.** The system consists of seven difference equations in sequences of seven variables $\left\{\pi_t, i_t, \pi_t^*, \widehat{Y}_t, \widehat{b}_t, \widehat{T}_t, \widehat{G}_t\right\}$:

(1) New Keynesian Philips curve (NKPC)

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa_0 \left(\eta_u + \eta_v\right) \left(\widehat{Y}_t - \Gamma \widehat{G}_t\right), \tag{1}$$

where

$$\kappa_0 = \frac{\left(1-\beta\theta\right)\left(1-\theta\right)}{\theta} \cdot \frac{1-\alpha}{1-\alpha+\alpha\epsilon},$$

$$\Gamma = \frac{\eta_u}{\eta_u + \eta_v} \in \left(0,1\right), \ \eta_u = \frac{Y\gamma}{Y-G}, \quad \eta_v = \frac{\alpha+\nu}{1-\alpha}.$$

(2) Intertemporal IS curve

$$\widehat{Y}_t - \widehat{G}_t = \mathbb{E}_t \left(\widehat{Y}_{t+1} - \widehat{G}_{t+1}\right) - \sigma(i_t - \mathbb{E}_t \pi_{t+1} - r_t^n), \tag{2}$$

where

$$\sigma = \frac{C}{\gamma Y}, \quad r_t^n = -\ln\beta - \Delta_t.$$

(3) Monetary policy rule

$$i_t = \max\left\{-\ln\beta + \phi_\pi \pi_t^*, \ 0\right\}. \tag{3}$$

(4) AIT rule

$$\pi_t^* = \rho \pi_{t-1}^* + (1-\rho)\pi_t. \tag{4}$$

(5) Fiscal policy rule

$$\widehat{T}_t = \phi_b \widehat{b}_{t-1} + \varepsilon_t^{\tau}. \tag{5}$$

(6) The government budget constraint

$$\beta \widehat{b}_t - \frac{\beta b}{Y}\left(i_t + \ln \beta\right) + \widehat{T}_t = \widehat{b}_{t-1} + \widehat{G}_t - \frac{b}{Y}\pi_t. \tag{6}$$

(7) Government spending

$$\widehat{G}_t = \rho_g \widehat{G}_{t-1} + \varepsilon_t^g. \tag{7}$$

In the system above, π_t, π_t^*, i_t, r_t^n, Y_t, G_t, b_t, and T_t represent respectively the inflation rate, the inflation rate target, the (continuously compounded) nominal interest rate, the real natural interest rate, real output, real government spending, real government debt (principal plus interest), and real lump-sum taxes. Assume that there is zero inflation in a deterministic steady state. In such steady state the nominal interest rate is equal to the real interest rate $-\ln \beta$. Let a variable without a time-subscript denote its steady-state value. Define

$$\widehat{Y}_t = \frac{Y_t - Y}{Y},\ \widehat{G}_t = \frac{G_t - G}{Y},\ \widehat{T}_t = \frac{T_t - T}{Y},\ \widehat{b}_t = \frac{b_t - b}{Y}.$$

The variable Δ_t represents an exogenous shock to the natural rate, which can be microfounded by introducing a preference shock. In addition, there are two independent white noise innovations ε_t^{τ} and ε_t^g in equations (5) and (7), respectively.

The parameters α, β, γ, ϵ, ν, and θ are the capital share, the household's subjective discount factor, the coefficient of relative risk aversion, elasticity of substitution of differentiated goods, the inverse Frisch elasticity of labor supply, and the probability of keeping price fixed in any period, respectively.

Equations (1) and (2) are the NKPC (accounting for the impact of government spending) and the Euler equation (intertemporal IS curve), respectively. The term κ_0 represents the slope of the NKPC curve in absence of government spending and reflects the standard Calvo measure of price stickiness (with $\kappa_0 \to \infty$ as prices become fully flexible). Let $\kappa \equiv \kappa_0 \left(\eta_u + \eta_v\right)$. Under flexible prices, we have $\partial \widehat{Y}_t / \partial \widehat{G}_t = \Gamma$ and thus the government spending multiplier on output is equal to $\Gamma \in (0, 1)$.

Equation (3) describes the monetary policy rule, according to which the central bank reacts to the AIT π_t^* with strength parameter ϕ_π. This rule also incorporates a zero lower bound on the nominal interest rate. The AIT π_t^* satisfies (4), which is equal to an exponential moving average of the current and past actual inflation rates (Woodford (2003, p.94) and Budianto, Nakata, and Schmidt (2020)). The literature typically assumes that the inflation target is equal to an arithmetic moving average of the current and past actual inflation rates (e.g., ??). As discussed by Budianto, Nakata, and Schmidt (2020), using exponential moving average economizes on the number of state variables and thereby facilitates the solution without changing the key insights. The usual inflation targeting is a special case with $\rho = 0$. When $\rho = 1$, we obtain the price-level targeting rule.

Equation (5) describes the fiscal policy rule as in Leeper (1991) and Woodford (1996), according to which the fiscal authority adjusts lump-sum taxes in response to changes of lagged real debt with strength parameter ϕ_b.[2] Equation (6) is the government's intertemporal budget constraint. The government issues nominal debt and collects nominal taxes to finance its nominal spending and interest cost on its existing debt level. Combining (5) and (6), we obtain the debt dynamics

$$\widehat{b}_t = \frac{1}{\beta}(1-\phi_b)\widehat{b}_{t-1} + \frac{1}{\beta}\widehat{G}_t + \frac{b}{Y}(i_t + \ln\beta) - \frac{b}{\beta Y}\pi_t - \frac{1}{\beta}\varepsilon_t^{\tau}. \tag{8}$$

Equation (7) shows that government spending follows an exogenous AR(1) process. The parameter $\rho_g \in [0,1)$ describes the persistence of government spending.

III.2. **Calibration.** Unless noted otherwise, we adopt the following baseline parameter values. One period in the model corresponds to one quarter. The discount factor is set at $\beta = 0.995$, which implies a steady state (annualized) real interest rate of about 2%. Set the relative risk aversion parameter $\gamma = 1$. Set the capital elasticity parameter $\alpha = 0.33$ as in the business cycle literature. Following Gali (2020), we assume $\nu = 5$, implying that the Frisch elasticity of labor supply is equal to 0.2. As in Galí (2015), we set $\epsilon = 9$, implying a 12.5 percent steady-state price markup. Set $\theta = 0.75$, implying an average price duration of four quarters, a value consistent with much of the empirical micro and macro evidence. According to the US anual data from 1950 to 2019, the average government spending to GDP ratio is about 11% and the average government debt to GDP ratio is about 36%. Thus we set $G/Y = 0.11$ and $b/Y = 1.44$. Set $\rho_g = 0.5$.

To fully solve for the equilibrium dynamics, we need to assign values for the policy parameters ϕ_π and ϕ_b. These values depend on a particular fiscal-monetary policy regime, and thus we will return to this issue after we study equilibrium determinacy.

We suppose that the economy is initially at the deterministic steady state and there is no natural rate shock ($\Delta_t = 0$ for all t) in normal times when the ZLB constraint does not bind. To enter a liquidity trap when the ZLB constraint binds, we set $\Delta_t = 0.01$ for $0 \le t \le 5$ and $\Delta_t = 0$ for all $t > 5$, so that the annual natural rate stays at -2% for 6 quarters only as in Gali (2020). Assume that all agents have perfect foresight and we focus on perfect foresight numerical solutions.

[2] More precisely, Leeper (1991) assumes that taxes respond to changes of the lagged real princpal value of debt. Here we follow Woodford (2003) by assuming debt includes both principal and interest.

III.3. **Definition of Fiscal Multipliers.** The main goal of our paper is to study fiscal multipliers. We define the taxation multiplier $TM_t^y(j)$ at horizon $j \geq 0$ on output (y) as the impulse response of output in period $t+j$ to a unit (lump-sum) tax cut in period t and define the government spending multiplier $GSM_t^y(j)$ as the impluse response of output in period $t+j$ to a unit increase in government spending in period t. One unit corresponds to a one percent of steady-steady output. We call the multiplier at $j=0$ the impact multiplier. For convenience we set $t=0$ throughout the paper and supress this subscript for all fiscal multipliers. Similarly, we can define fiscal multipliers on other variables such as inflation and real debt. We define the cumulative fiscal multipliers as the cumulative responses of a unit tax cut or government spending increase.

During normal times, the model admits a log-linear solution and thus we can analytically compute fiscal multipliers for any horizon j (e.g., Beck-Friis and Willems (2017)). In particular, the government spending multiplier on output at horizon j is equal to $GSM^y(j) = \partial\widehat{Y}_j/\partial\varepsilon_0^g$ and the cumulative government spending multiplier on output is equal to $(1-\rho_g)\sum_{t=0}^{\infty}\partial\widehat{Y}_t/\partial\varepsilon_0^g$ (e.g., Gali (2020)). We will study this case in Section 3.

When the ZLB constraint binds due to negative shocks to natural rates, the economy enters a liquidity trap and the model solution will be nonlinear. The computation of fiscal multipliers will be more complicated and needs numerical methods. Woodford (2011) argues that the duration of fiscal stimulus is important for the size of fiscal multipliers (see Eggertsson (2009), Cogan et al (2010), and Miao and Ngo ()). If the government spending follows a persistent AR(1) process as in (7), then the government spending multiplier will be much smaller because the increased government spending after the economy leaves the liquidity trap has a negative effect on consumption and output in the liquidity trap.

For this reason, we only consider the impact of temporary fiscal stimulus with $\rho_g = 0$. In particular, we consider two policy experiments: First, suppose that the government spending increase is purely temporary by setting $\varepsilon_0^g = 1\%$ and $\varepsilon_t^g = 0$ for all $t > 0$. Second, suppose that the spending increase is evenly spread out during the entire episode of the negative demand shock; that is, set $\varepsilon_t^g = 1/6\%$, for $t = 0, 1, .., 5$, and $\varepsilon_t^g = 0$, for $t > 5$.

Let $\{\widehat{Y}_t^a\}$ $(\{\widehat{Y}_t^b\})$ denote the path of output after (before) the temporary government spending increase. We then define the impact government spending multiplier on output as $\left(\widehat{Y}_0^a - \widehat{Y}_0^b\right)/\varepsilon_0^g$ and the cumulative government spending multiplier on output as $\sum_{t=0}^{\infty}\left(\widehat{Y}_t^a - \widehat{Y}_t^b\right)/\sum_{t=0}^{\infty}\varepsilon_t^g$. We will study this case in Section 4.

IV. Fiscal Multipliers in Normal Times

In this section we first analyze equilibrium determinacy in normal times when the ZLB constraint does not bind. Then we study the effects of a tax cut and an increase in government purchases on the economy in normal times.

IV.1. **Equilibrium Determinacy.** To study equilibrium determinacy, it suffices to consider the perfect foresight case by assuming $\Delta_t = \varepsilon_t^\tau = \varepsilon_t^g = 0$ for all t. We can then write the equilibrium system in a matrix form:

$$\begin{bmatrix} 1 & \sigma & 0 & 0 \\ 0 & \beta & 0 & 0 \\ 0 & \rho-1 & 1 & 0 \\ 0 & \frac{b}{Y} & -\beta\frac{b}{Y}\phi_\pi & \beta \end{bmatrix} \begin{bmatrix} \widehat{Y}_{t+1} \\ \pi_{t+1} \\ \pi_{t+1}^* \\ \widehat{b}_{t+1} \end{bmatrix} = \begin{bmatrix} 1 & 0 & \phi_\pi\sigma & 0 \\ -\kappa & 1 & 0 & 0 \\ 0 & 0 & \rho & 0 \\ 0 & 0 & 0 & 1-\phi_b \end{bmatrix} \begin{bmatrix} \widehat{Y}_t \\ \pi_t \\ \pi_t^* \\ \widehat{b}_t \end{bmatrix} + \begin{bmatrix} \widehat{G}_{t+1} - \widehat{G}_t \\ \kappa\Gamma\widehat{G}_t \\ 0 \\ \widehat{G}_{t+1} \end{bmatrix}.$$

Because $\widehat{G}_t$ is an exogenously given stationary process, we can ignore the last forcing vector when analyzing determinacy. Then the predetermined variables are π_t^* and $\widehat{b}_t$ and the non-predetermined variables are $\widehat{Y}_t$ and π_t. Write the above system as $X_{t+1} = \Omega X_t$, where $X_t = \left[\widehat{Y}_t, \pi_t, \pi_t^*, \widehat{b}_t\right]'$ for some matrix Ω. To have a unique bounded equilibrium, we need Ω to have two eigenvalues inside the unit circle and two eigenvalues outside the unit circle.

Following Woodford (1996, 2003), we define a fiscal rule (tax rule) as locally Ricardian if when substituted into the government budget constraint (6) it implies that $\left\{\widehat{b}_t\right\}$ remains bounded for all bounded paths of endogenous variables $i_t, \pi_t, \widehat{Y}_t$ and exogenous variable $\widehat{G}_t$. By (8), we deduce that the tax rule in (5) is locally Ricardian if and only if $|(1-\phi_b)/\beta| < 1$. In Appendix ?? we show that the matrix Ω has an eigenvalue $(1-\phi_b)/\beta$. The remaining three eigenvalues are the roots to the following characteristic equation:

$$f(\lambda) \equiv \lambda^3 - \left(\frac{1+\kappa\sigma}{\beta} + 1 + \rho\right)\lambda^2 + \frac{1}{\beta}\left[1+\rho+\beta\rho+(\phi_\pi+\rho(1-\phi_\pi))\kappa\sigma\right]\lambda - \frac{\rho}{\beta} = 0. \quad (9)$$

Let λ_1, λ_2, and λ_3 denote the three roots with $|\lambda_1| \geq |\lambda_2| \geq |\lambda_3|$. Studying the stability of these eigenvalues in Appendix ??, we obtain the following result:

Proposition 1. Suppose that $\phi_\pi \geq 0$, $0 \leq \rho < 1$. (i) If the fiscal policy is locally Ricardian ($|(1-\phi_b)/\beta| < 1$), then the necessary and sufficient condition for determinacy is given by $\phi_\pi > 1$. (ii) If the fiscal policy is locally non-Ricardian ($|(1-\phi_b)/\beta| > 1$), then the necessary and sufficient condition for determinacy is given by $\phi_\pi < 1$.[3]

We call the first case in Proposition 1 the monetary regime and the second case the fiscal regime as in Leeper (1991). According to Leeper (1991), fiscal policy is passive (active) and

[3]We can also easily show that the equilibrium is indeterminate if $|(1-\phi_b)/\beta| < 1$ and $\phi_\pi < 1$ and there is no bounded equilibrium if $|(1-\phi_b)/\beta| > 1$ and $\phi_\pi > 1$.

monetary policy is active (passive) in the monetary (fiscal) regime. Proposition 1 shows that if the fiscal policy is locally (non-) Ricardian, then determinacy requires monetary policy to satisfy (violate) the Taylor principle ($\phi_\pi > 1$). The intuition is that at least in the long run, the nominal interest rates should rise by more than the increase in the inflation rate for inflation dynamics to be stabilized. For the AIT rule (4), the interest rate target rises by the same amount as the actual inflation rate in the long run. Thus, according to the monetary rule (3) in normal times, we must have $\phi_\pi > 1$.

Proposition 1 implies that the policy parameter space for determinacy under the general AIT rule (4) is independent of ρ, and thus it is the same as that in the sticky price model of Woodford (1996, 2003) and in the flexible price model of Leeper (1991). In Appendix A we present the determinacy result for more general monetary policy rules in which nominal interest rates also respond to the output gap. We find that the policy parameter space for determinacy depends on the parameter ρ.

IV.2. **Monetary Regime.** In this subsection we compute fiscal multipliers by computing the log-linearized equilibrium solution. We introduce $\widehat{G}_t$ to the state vector and let $X_t = \left[\widehat{Y}_t, \pi_t, \pi_t^*, \widehat{b}_t, \widehat{G}_t\right]'$. In Appendix A we use the Sims (2002) method to show that the solution takes the form

$$X_t = HX_{t-1}^p + H_\tau \varepsilon_t^\tau + H_g \varepsilon_t^g, \tag{10}$$

where H, H_τ, and H_g are some conformable matrices and $X_{t-1}^p = (\pi_{t-1}^*, \widehat{b}_{t-1}, \widehat{G}_{t-1})$ denote the vector of the predetermined state variables. Then the fiscal multipliers can be read from the matrices H_τ and H_g. Since the size of a fiscal multiplier depends on a particular policy regime, we introduce a subscript M or F to denote the multipliers in the monetary or fiscal regime, respectively.

In Appendix ?? we prove the following result.[4]

Proposition 2. Suppose that $\phi_\pi > 1$ and $|(1-\phi_b)/\beta| < 1$ so that the economy is in the monetary regime. Then (i) $|\lambda_1| \geq |\lambda_2| > 1$ and $0 < \lambda_3 < \rho$, (ii) the taxation multipliers are equal to zero

$$TM_M^y(j) = 0,\ TM_M^\pi(j) = 0,$$

[4]As $\rho \to 0$, Proposition ?? is reduced to the result for the standard inflation targeting rule in Woodford (??) and Beck-Friis and Willems (2017).

and (iii) the government spending multipliers are given by

$$GSM_M^y(j) = \lambda_3^j \frac{(1-\beta\lambda_3)(\rho-\lambda_3)(1-\rho_g)(1-\Gamma)}{J_2} + \rho_g^j \frac{J_1}{J_2}, \tag{11}$$

$$GSM_M^\pi(j) = \frac{(1-\rho_g)(1-\Gamma)\kappa}{J_2}\left[\lambda_3^j(\rho-\lambda_3) + \rho_g^j(\rho_g-\rho)\right], \tag{12}$$

$$GSM_M^{\pi^*}(j) = \frac{(1-\rho)(1-\rho_g)(1-\Gamma)\kappa}{J_2}\left[-\lambda_3^{j+1} + \rho_g^{j+1}\right], \tag{13}$$

where J_1 and J_2 are given by

$$J_1 = (\rho_g-\rho)(1-\rho_g)(1-\beta\rho_g) + \rho_g\left[\rho + \phi_\pi(1-\rho) - \rho_g\right]\Gamma\kappa\sigma,$$
$$J_2 = (\rho_g-\rho)(1-\rho_g)(1-\beta\rho_g) + \rho_g\left[\rho + \phi_\pi(1-\rho) - \rho_g\right]\kappa\sigma.$$

In the monetary regime, the Ricardian equivalence holds so that changes in lump-sum taxes do not affect output and inflation. But government spending affects the economy through two effects: First, an increase in government spending crowds out consumption by the resource constraint so that consumption decreases and labor supply increases. Second, an increases in government spending raises aggregate demand. Due to sticky prices, firms cannot fully raise prices in response to the higher demand. Instead, they lower their markup and increase production, thereby raising labor demand. The net effect is that equilibriun labor rises and hence output rises.

To better understand the size of the fiscal multipliers and their comparative static properties, we consider the special case of $\rho_g = 0$.

Corollary IV.1. *Suppose the conditions in Proposition 2 hold. Let $\rho_g = 0$. Then we have*

$$GSM_M^y(j) = \begin{cases} -\frac{(1-\beta\lambda_3)(\rho-\lambda_3)(1-\Gamma)}{\rho} + 1 \in (\Gamma, 1), & \text{if } j = 0, \\ -\lambda_3^j \frac{(1-\beta\lambda_3)(\rho-\lambda_3)(1-\Gamma)}{\rho} < 0, & \text{if } j \geq 1, \end{cases} \tag{14}$$

$$GSM_M^\pi(j) = \begin{cases} \frac{(1-\Gamma)\kappa\lambda_3}{\rho} > 0, & \text{if } j = 0, \\ -\lambda_3^j \frac{(1-\Gamma)\kappa(\rho-\lambda_3)}{\rho} < 0, & \text{if } j \geq 1, \end{cases} \tag{15}$$

$$GSM_M^{\pi^*}(j) = \lambda_3^j \frac{(1-\rho)(1-\Gamma)\kappa\lambda_3}{\rho} > 0, \quad j \geq 0. \tag{16}$$

This corollary shows a positive transitory government spending shock boosts output and inflation in the current period, but leads to lower output and inflation in the future periods before reverting to the steady state. This is different from the result in the standard model with the inflation target rule (Woodford (??) and Beck-Friis and Willems (2017)), which is the special case of Corollary 1 as $\rho \to 0$:

$$GSM_M^y(j) = \begin{cases} \frac{1+\phi_\pi \kappa\sigma\Gamma}{1+\phi_\pi\kappa\sigma}, & \text{if } j = 0, \\ 0, & \text{if } j \geq 1, \end{cases} \quad GSM_M^\pi(j) = \begin{cases} \frac{(1-\Gamma)\kappa}{1+\phi_\pi\kappa\sigma}, & \text{if } j = 0, \\ 0, & \text{if } j \geq 1. \end{cases}$$

The intuition is illustrated by the impuse response functions displayed in Figure 1. We set $\phi_\pi = 1.5$ and $\phi_b = 0.0177$ so that economy stays in the monetary regime. The choice of $\phi_b = 0.0177$ implies that 5% of the deviation from the target debt ratio is corrected over four quarters, i.e., $[(1-\phi_b)/\beta]^4 = 0.95$ by (8). This choice only affects debt dynamics, but not other variables due to the Ricardian equivalence.

Under the AIT rule (4), nominal interest rates react to the average π_t^* of current and past inflation rates. As π_t^* is a slow-moving predetermined state variable, the nominal interest rate i_t gradually declines to its steady state value, even though the government spending shock is purely temporary. Thus the real interest rate $r_t = i_t - \mathbb{E}_t\pi_{t+1}$ also gradually declines to its steady state value. As a result, consumption stays at low values for a long-time before reverting to the steady state due to the intertemporal substitution effect. Thus, output rises on impact by the magnitude less than the increase in government spending, and then output declines below the steady state before reverting to the steady state. This is in contrast to the case with the inflation targeting rule ($\rho = 0$), in which the economy revert to its steady state values immediately after the initial period.

Moreover, inflation dynamics display a makeup feature under the AIT rule in the sense that current inflation is followed by future deflation. The intuition is that the inflation target rises with the past inflation and thus the future nominal interest rate also increases with past inflation. As the future real interest rate also rises due to sticky prices, future aggregate demand declines, inducing future inflation to fall.

Figure 2 presents the fiscal multipliers against $\rho \in [0, 1)$ for different values of ρ_g. We find that, for any fixed ρ_g, the impact government spending multiplier on output increases with ρ, but the cumulative multiplier may not be monotonic with ρ. Moreover, the cummulative multiplier on output is smaller than the impact multiplier. Intuitively, under the AIT rule (4) with a higher ρ, the nominal interest rate rises less in response to an increased current inflation rate (see Figure 1). Thus the real interest rate also rises less in responses to an increased government spending on impact. This causes a weaker crowding-out effect on consumption so that the initial output response is larger. On the other hand, a higher ρ causes a more persistent effect on the nominal and real interest rates due to the slow-moving average inflation target. Thus the negative effect on future consumption and output is larger for a higher ρ. The size of the cumulative multiplier on output reflects the net effects on the

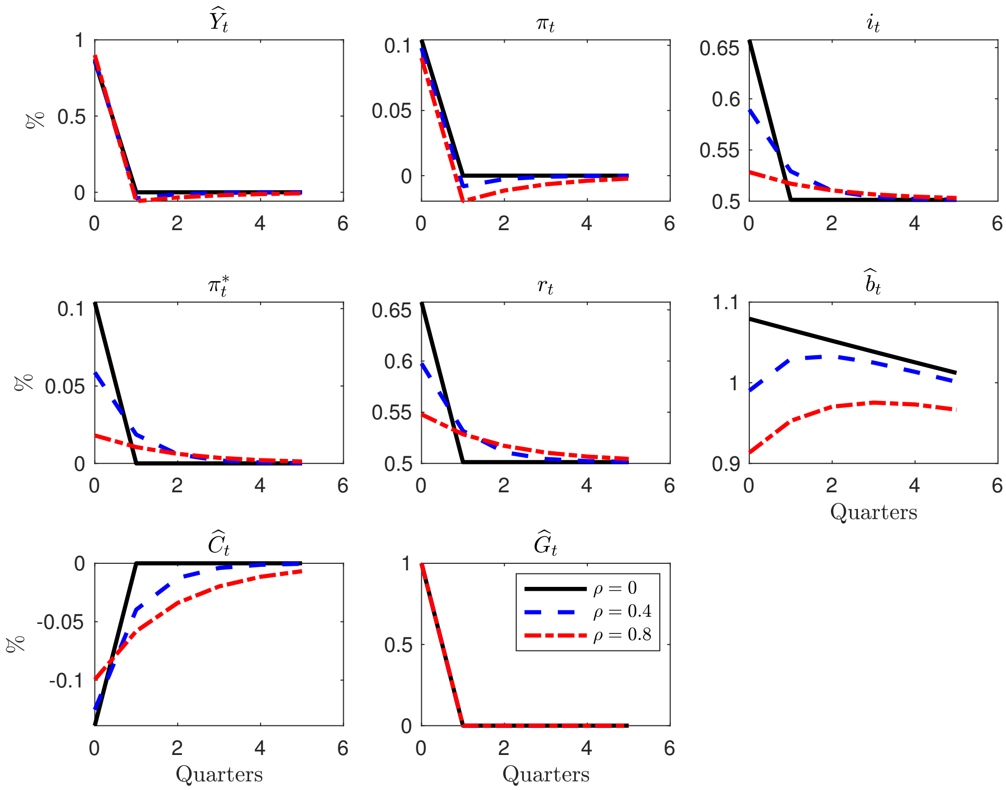

FIGURE 1. Dynamic Effects of Government Spending in the Monetary Regime. Note: we set $\phi_\pi = 1.5$ and $\phi_b = 0.0177$ so that the economy is in the monetary regime and 5% of the deviation from target in the debt ratio is corrected over four quarters.

current and future output, which are ambiguous. It turns out that the cumulative multiplier decreases with ρ for small values ρ_g, but increases with ρ_g for large values ρ_g.

Figure 2 shows that, for a fixed ρ, both impact and cummulative multiplier on output decreases with ρ_g. The intuition is that a more persistent government spending shock leads to higher expectations about future inflation and hence a higher real interest rate. As the household decreases consumption more due to the intertemporal substitution effect, the effect on output is smaller.

In the monetary regime, we have the usual comparative statics result for two parameters ϕ_π and θ (see, e.g., Beck-Friis and Willems (2017)). In particular, a higher θ implies that the prices are more skicky and thus the NKPC is flatter so that the government spending multiplier on output is larger. A more dovish monetary policy (lower ϕ_π) leads to a lower real interest rate hike and hence the government spending multiplier is larger. In the monetary regime, Ricardian equivalence holds so that the fiscal parameter ϕ_b does not affect output.

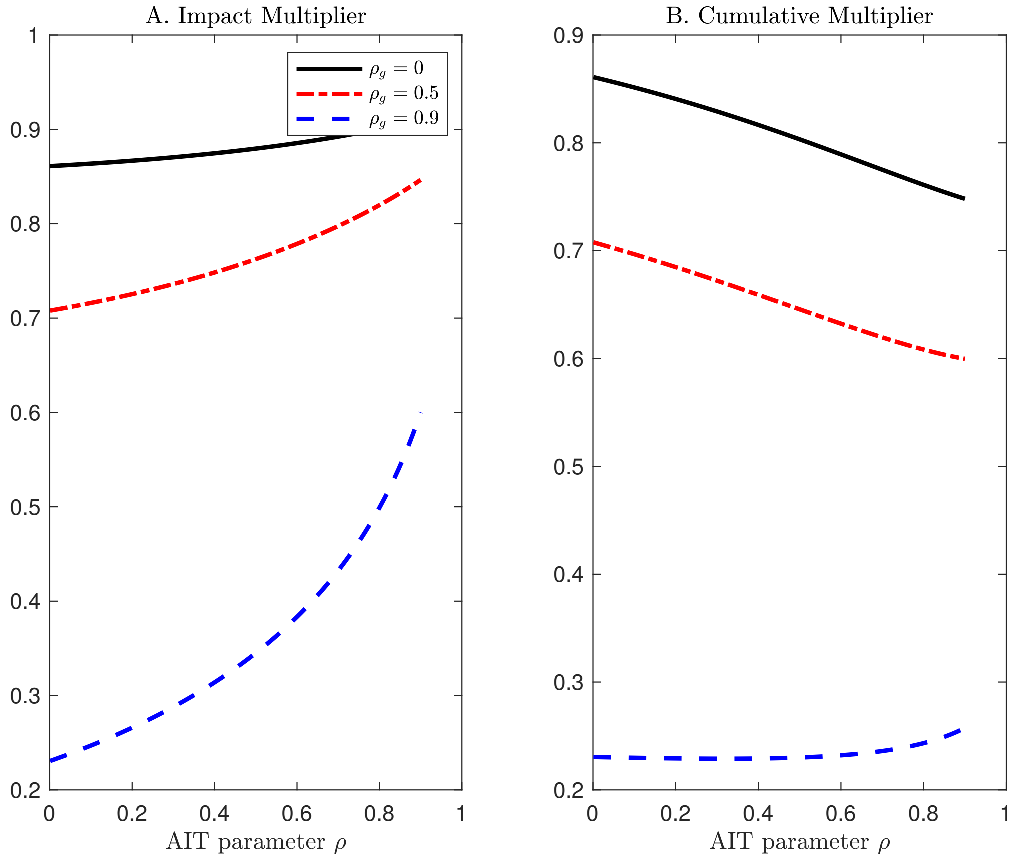

FIGURE 2. Government Spending Multipliers in the Monetary Regime

IV.3. **Fiscal Regime.** In the fiscal regime, we have $\phi_\pi > 1$ and $|(1-\phi_b)/\beta| < 1$ by Proposition 1. The log-linearized equilibrium solution still takes the form in (10). In Appendix ? we derive the following result:

Proposition 3. Suppose that $\phi_\pi < 1$ and $\phi_b < 1-\beta$ so that the economy is in the fiscal regime.[5] Then (i) $|\lambda_1| > 1 > \lambda_2 > \rho > \lambda_3 > 0$ and $\lambda_3 \in (0, \rho)$; (ii) the taxation multipliers are given by

$$TM_F^y(j) = \frac{1}{(1-\phi_b)b/Y}\frac{1}{\kappa}\left[\frac{\lambda_2^j(1-\beta\lambda_2)(\lambda_2-\rho)}{\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_2-\rho}{1-\phi_b-\beta\lambda_2}-\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_3-\rho}{1-\phi_b-\beta\lambda_3}}+\frac{\lambda_3^j(1-\beta\lambda_3)(\lambda_3-\rho)}{\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_3-\rho}{1-\phi_b-\beta\lambda_3}-\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_2-\rho}{1-\phi_b-\beta\lambda_2}}\right] > 0, \tag{17}$$

$$TM_F^\pi(j) = \frac{1}{(1-\phi_b)b/Y}\left[\frac{\lambda_2^j(\lambda_2-\rho)}{\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_2-\rho}{1-\phi_b-\beta\lambda_2}-\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_3-\rho}{1-\phi_b-\beta\lambda_3}}+\frac{\lambda_3^j(\lambda_3-\rho)}{\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_3-\rho}{1-\phi_b-\beta\lambda_3}-\frac{[1-\beta\phi_\pi(1-\rho)]\lambda_2-\rho}{1-\phi_b-\beta\lambda_2}}\right] > 0, \tag{18}$$

[5] If $\phi_b > 1+\beta$ and $\phi_\pi < 1$, the economy is also in the fiscal regime. We do not study this case in the paper.

and (iii) the government spending multipliers are given by

$$GSM_F^y(j) = GSM_M^y(j) + \sum_{k=0}^{\infty}\left(\frac{\beta}{1-\phi_b}\right)^k\left[\rho_g^k - \frac{b}{Y}\cdot GSM_M^{\pi}(k) + \beta\frac{b}{Y}\phi_\pi\cdot GSM_M^{\pi^*}(k)\right]\times TM_F^y(j), \tag{19}$$

$$GSM_F^{\pi}(j) = GSM_M^{\pi}(j) + \sum_{k=0}^{\infty}\left(\frac{\beta}{1-\phi_b}\right)^k\left[\rho_g^k - \frac{b}{Y}\cdot GSM_M^{\pi}(k) + \beta\frac{b}{Y}\phi_\pi\cdot GSM_M^{\pi^*}(k)\right]\times TM_F^{\pi}(j). \tag{20}$$

In the fiscal regime, the Ricardian equivalence does not hold and thus a lump-sum tax cut affects output and inflation. In this regime, a deficit-financed tax cut or government spending is not associated with sufficiently high future taxes to repay the debt. The household perceives the newly-issued government bonds as an increase to its nominal wealth, leading to increased consumption demand and generating positive taxation multipliers on output and inflation. The Ricardian equivalence fails not because of the presence of financial or real frictions, but rather because the government does not adjust real primary surpluses in response to the newly-issued debt.

More specifically, we rewrite the log-linearized government budget constraint (8) after plugging in the tax rule as

$$(1-\phi_b)\widehat{b}_{t-1} = \sum_{k=0}^{\infty}\left(\frac{\beta}{1-\phi_b}\right)^k\left(-\widehat{G}_{t+k} + \frac{b}{Y}\pi_{t+k} - \beta\frac{b}{Y}(i_{t+k}+\ln\beta) + \varepsilon_{t+k}^{\tau}\right). \tag{21}$$

This present-value equation holds because $|\beta/(1-\phi_b)| < 1$ in the fiscal regime. Similarly we can write the log-linearized household budget constraint in a present-value form. As argued by Woodford (1996), if prices and interest rates do not change, an increase in the present value of the government deficit increases the present value of "total consumption" that the representative household can afford, and thus induces an increase in the aggregate demand for goods. Equilibrium therefore requires adjustment of prices and/or interest rates so as to preserve equality between the value of outstanding government liabilities and the present value of future government surpluses.

Figures 3 presents the impulse responses to a purely temporary positive government spending shock for three different values of ρ.[6] For this figure we set $\phi_\pi = 0.8$ and $\phi_b = 0.0025$. As discussed earlier, an increase in government spending raises consumption, output, inflation, and the nominal interest rate. But the real interest rate declines on impact because of the weak response of the nominal interest rate by the passive monetary policy ($\phi_\pi = 0.8$).

Unlike Figure 1 in the monetary regime, Figure 3 also shows that there is no inflation makeup in response to an increase in government spending in the fiscal regime with $\rho > 0$.

[6]The impulse responses to a tax cut are similar and will not be discussed.

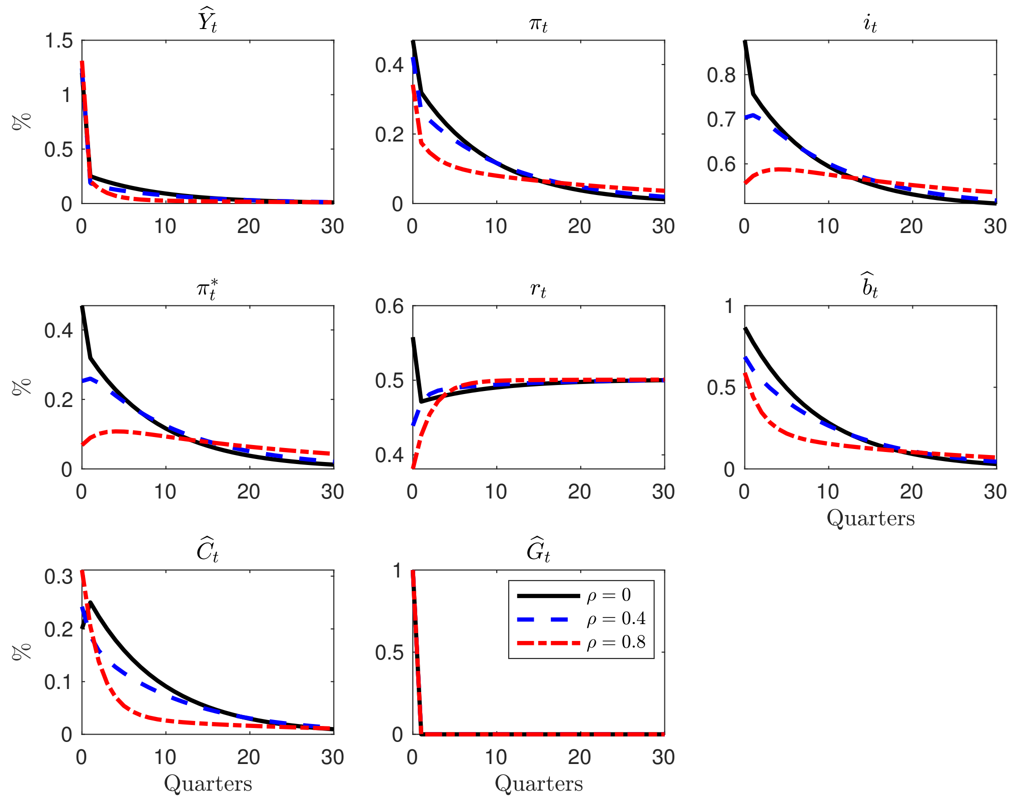

FIGURE 3. Dynamic Effects of Government Spending in the Fiscal Regime. Note: we set $\phi_\pi = 0.8$ and $\phi_b = 0.0025$ so that the economy is in the fiscal regime.

We are unable to prove this result formally. But we can prove this result for a tax cut in the fiscal regime with $\rho > 0$ because Proposition ? shows that $TM_F^{\pi}(j) > 0$ and $TM_F^{y}(j) > 0$ for all $j \geq 0$. Intuitively, the rise of the nominal interest rate in response to a tax cut generates a positive wealth effect so that aggregate demand stays high for a long time and gradually declines to its steady state level. Thus inflation also gradually declines to its steady state.

For the government spending shock, equations (19) and (20) reveal the intuition that the government spending multipliers in the fiscal regime are equal to the government spending multipliers in the monetary regime $GSM_M^{y,\pi}(j)$, plus a nominal wealth effect. Government spending in the fiscal regime still generates labor supply and labor demand effects as in the monetary regime. Real labor demand rises because firms cannot fully adjust prices to meet the extra nominal demand. Real labor supply increases to equate the marginal rate of substitution between labor and consumption to the real wage. Following Beck-Friis and Willems (2020), we refer to these effects as Keynesian.

On top of these effects, higher government spending in the fiscal regime also increases the nominal wealth of the private sector, since it is financed by not fully backed government bonds, which are the household's wealth. To better understand this nominal wealth effect, we consider the simple case of $\rho_g = 0$:

Corollary IV.2. *Suppose that the conditions in Proposition 3 hold. If $\rho_g = 0$, then the government spending multipliers are given by*

$$GSM_F^y(j) = GSM_M^y(j) + \left[1 + \sum_{k=0}^{\infty} \left(\frac{\beta}{1-\phi_b}\right)^k \left[-\frac{b}{Y} \cdot GSM_M^{\pi}(k) + \frac{b}{Y}\beta\phi_\pi \cdot GSM_M^{\pi^*}(k)\right]\right] \times TM_F^y(j), \tag{22}$$

$$GSM_F^{\pi}(j) = GSM_M^{\pi}(j) + \left[1 + \sum_{k=0}^{\infty} \left(\frac{\beta}{1-\phi_b}\right)^k \left[-\frac{b}{Y} \cdot GSM_M^{\pi}(k) + \frac{b}{Y}\beta\phi_\pi \cdot GSM_M^{\pi^*}(k)\right]\right] \times TM_F^{\pi}(j). \tag{23}$$

where $GSM_M^y(j)$, $GSM_M^{\pi}(j)$, $GSM_M^{\pi^*}(j)$, $TM_F^y(j)$, and $TM_F^{\pi}(j)$ are given by (14), (15), (16), (17) and (18), respectively.

In terms of the wealth effect, a purely temporary increase in government spending is equivalent to a debt-financed tax cut in the fiscal regime, which explains the presence of the second term, $TM_F^y(j)$, in equations (22) and (23).

The third term

$$-\sum_{k=0}^{\infty} \left(\frac{\beta}{1-\phi_b}\right)^k \frac{b}{Y} \cdot GSM_M^{\pi}(k).$$

reflects the inflation effect because government spending in the fiscal regime still brings about Keynsian inflation as in the monetary regime. Inflation depresses the real value of the outstanding government bonds. It acts like a tax on the household's wealth and thus lowers aggregate demand. On the other hand, inflation increases the nominal interest rate as the nominal interest rate responds positively to average inflation under the AIT rule (provided that $\phi_\pi > 0$), which increases aggregate demand through the neo-Fisherian effect in the sense that a high nominal interest rate raises returns on nominal bonds and hence the household's wealth. This effect is captured by the term

$$\sum_{k=0}^{\infty} \left(\frac{\beta}{1-\phi_b}\right)^k \frac{b}{Y}\beta\phi_\pi \cdot GSM_M^{\pi^*}(k).$$

The net impact of the Keynesian inflation on the household's wealth is then equivalent to that of a tax hike of the same size. Thus we multiply the above two terms by $TM_F^y(j)$. To understand the above two terms, we substitute (4) into (21) to illustrate the impact of a temporay change in government spending ($d\varepsilon_t^g$) or taxes ($-d\varepsilon_t^\tau$) :

$$d\varepsilon_t^g = -d\varepsilon_t^\tau = \sum_{k=0}^{\infty} \left(\frac{\beta}{1-\phi_b}\right)^k \left[\frac{b}{Y} d\pi_{t+k} - \beta\frac{b}{Y}\phi_b d\pi_{t+k}^*\right].$$

Thus an increase in government spending or a tax cut must be accompanied by the adjustment of future actual inflation and average inflation target.

For the standard inflation targeting rule ($\rho = 0$), we have $\pi_t^* = \pi_t$ for all t. We can then obtain the result in Beck-Friis and Willems (2020) as a special case of ours.

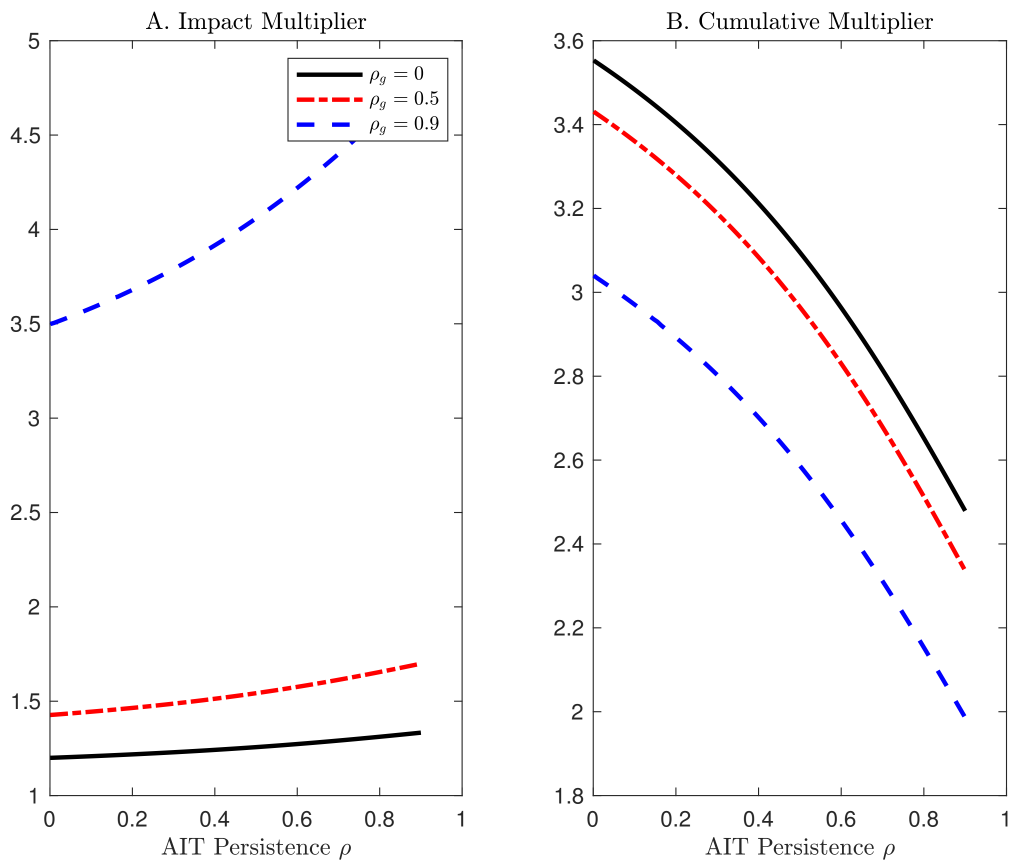

FIGURE 4. Government Spending Multipliers in the Fiscal Regime

Figure 4 presents the impact mulitpliers and the cumulative mulitpliers against ρ in the fiscal regime for several values of ρ_g. Compared to the multipliers in the monetary regime, three features stand out. First, the impact multiplier in the fiscal regime is much larger and larger than 1. Intuitively, the monetary policy response coefficient ϕ_π is smaller than 1 in the fiscal regime, so the increase in the nominal interest rate is smaller, resulting in a larger impact multiplier for each value of ρ. Moreover, the nominal wealth effect absent in the monetary regimes causes consumption to rise on impact.

Second, the cumulative multiplier is larger than the impact multiplier. This is due to the dominating force of the nominal wealth effect discussed earlier. As a result, output stays above its steady state level for a long time before reverting to the steady state even if the government spending shock is only transitory.

Third, both the impact and cumulative multipliers in the fiscal regime are larger if the persistence in government spending is higher, unlike in the montary regime. This is because a more persistent government spending shock leads to a larger nominal wealth effect in the fiscal regime.

Regarding comparative statics, we find that the government spending and taxation multipliers on output are larger if the price is stickier (larger θ). This is due to the larger nominal wealth effect for a larger θ, absent in the monetary regime. Also unlike in the monetary regime, the impact mutipliers on output decrease with ϕ_π, but the cumulative mutipliers increase with ϕ_π. The latter property is due to the larger nominal wealth effect on the future output generated by a larger nominal interest rate response.

The more interesting comparative statics result is for the fiscal policy parameter ϕ_b. Following Billi and Walsh (2021), we consider two irresponsible fiscal policies: (i) taxes do not respond to debt ($\phi_b = 0$); (ii) the government cuts taxes in response to the previous debt (e.g., $\phi_b = -0.0025$). We find that the government spending and taxation multipliers are larger if ϕ_b is smaller. Intuitively, an increase in government spending reduces the present value of primary surpluses relative to the real value of public bonds. As a result, households feel wealthier and increase consumption demand. With a smaller ϕ_b, the present value of primary surplus would be even smaller, due to the weaker increase in tax revenue in response to the newly-issued public bonds. This implies that the nominal wealth effect is stronger, and hence the fiscal multipliers are larger for a smaller ϕ_b.

V. Fiscal Multipliers in a Liquidity Trap

In this section we study the effectiveness of a debt-financed fiscal stimulus in stabilizing the economy when it is hit by a temporary adverse demand shock. The demand shock is large enough to prevent the central bank from fully stabilizing output and inflation, due to a ZLB constraint on the nominal rate. We study the responses of the economy starting from the deterministic steady state.

As described in Section 2.2, we set $\Delta_t = 0.01$ for $0 \leq t \leq 5$ and $\Delta_t = 0$ for $t > 5$ so that the natural rate unexpectedly drops to -2% for six quarters, and subsequently reverts back to its steady state value of $+2\%$ (in annualized terms). As in the previous section, the impact of the fiscal stimulus on the economy depends on a particular fiscal-monetary policy regime.

V.1. **Monetary Regime.** We start by the monetary regime in which $\phi_\pi = 1.5$ and $\phi_b = 0.0177$. We first consider the case of no fiscal response (i.e., $\varepsilon_t^g = \varepsilon_t^\tau = 0$ for all t). Figure 5 presents the dynamic responses of the economy for different values of ρ. This figure shows that economy enters a recession in that output and consumption decline and there is deflation.

For the usual inflation targeting rule ($\rho = 0$), the ZLB constraint binds for $0 \leq t \leq 3$. The averge inflation targeting rule helps mitigate the adverse demand shock because the initial drop of output and consumption is smaller. Moreover, the initial drop of consumption, output, and inflation decreases with ρ. But the duration of the binding ZLB constraint is not monotonic with ρ. In particular, when $\rho = 0.4$, the ZLB constraint binds for 5 periods, but it does not bind for all $t \geq 0$ when $\rho = 0.8$. The intuition is as follows: Under the AIT rule, the nominal interest rate responds to the average inflation target instead of the current actual inflation. The larger is ρ, the average inflation target is more persistent. Thus the nominal interest rate stays low for a longer time even after the adverse natural rate shock vanishes for $t \geq 6$. This is also true for the real interest rate due to sticky prices. By contast for the usual inflation targeting rule with $\rho = 0$, the nominal and real interest rates revert back to the steady state for $t \geq 6$.

Anticipating future low interest rates for a long time given the AIT rule, the forward-looking household tends to save less and consume more. In this sense, the AIT rule plays a similar role of forward guidence. This explains why the adverse effect on output and consumption is smaller for a larger value of ρ.

The preceding discussion shows that the ZLB constraint is more likely to bind for a larger ρ. On the other hand, as the inflation rate drops less for a larger ρ and as the average inflation target decreases with the actual inflation for a fixed ρ, the nominal interest rate decreases less for a larger ρ under the AIT rule so that it is less likely to hit the ZLB for a larger ρ. These two effects imply that the duration of the ZLB episode is not monotonic with ρ.

Next we consider the impact when the government increases spending by 1% of steady-state output only at $t = 0$ (i.e., $\rho_g = 0$ and $\varepsilon_0^g = 1\%$). Figure 6 presents the impact and cumulative multipliers against ρ. The dashed lines show the case without ZLB constraint and the solid lines show the case with the ZLB constraint. We find several interesting results. First, the impact and cumulative multipliers with the ZLB constraint are higher than without the ZLB constraint. Intuitively, the dampening response of monetary policy in the form of higher nominal rates is absent at the ZLB. When ρ is sufficiently large, the ZLB constraint does not bind so that the multipliers in both cases are identical. Interestingly, the impact and cumulative multipliers when the ZLB constraint binds for $\rho = 0$ are equal to 1, implying that there is no crowding out effect on consumption. The intuition can be gained by writing consumption as the present value of the future deviation of the real interest rates from the natural rates using the intertemporal IS equation (2). At the ZLB, the real interest rate is equal to the expected future inflation rate. As the government spending is purely temporary, it has no impact on the future inflation rates and norminal interest rates for $\rho = 0$. In this case consumption will not respond on impact.

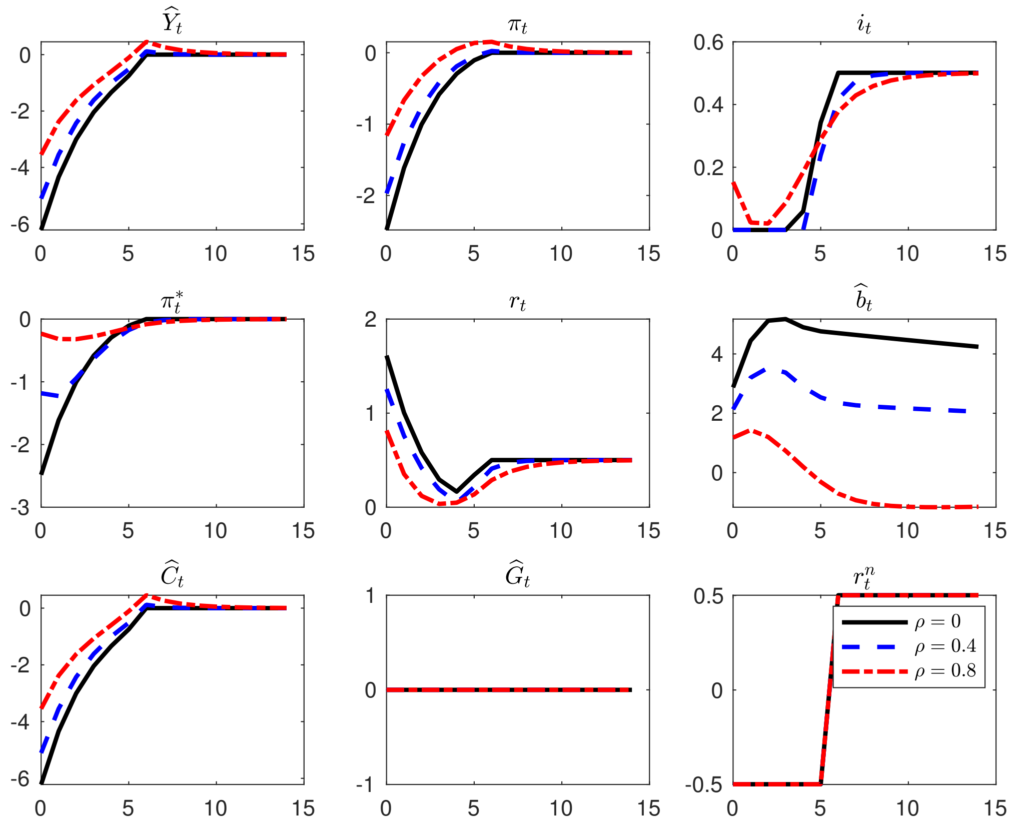

FIGURE 5. Dynamic responses to a large negative natural rate shock in the monetary regime with no fiscal response. Note: we set $\phi_\pi = 1.5$ and $\phi_b = 0.0177$ so that the economy is in the monetary regime and 5% of the deviation from target in the debt ratio is corrected over four quarters.

Second, the impact multiplier on output first declines as ρ gradually increases from zero until it reaches a sufficiently high value such that the ZLB constraint does not bind. From that value of ρ on, the impact multiplier increases with ρ as in Section 3.2 for the normal times. Intuitively, the increased government spending generates inflation on top of the adverse natural rate shock (see Panel C of Figure 6). Then the future AIT rises and thus the future nominal interest rates rise too under the AIT rule. After the economy leaves the liquidity trap, the damping response of the AIT monetary policy causes future inflation to fall. This effect is larger for a larger ρ. In the liquidity trap when the ZLB constraint binds, anticipating future lower inflation, the real interest is higher for a larger ρ. We call this effect the anticipated inflation channel of government spending. Due to this channel, the stimulative effect on consumption and output will be smaller for a larger ρ in a liquidity trap.

Panel D of Figure 6 shows that the initial nominal interest rate is at the ZLB for $\rho \in [0, 0.7]$. When ρ increases from 0.7 to 0.79, the initial nominal interest rate is away from

ZLB and responds to the government spending shock, but the nominal interest rate in the second still hits the ZLB. Thus the multipliers on output are larger than those without the ZLB constraint for $\rho \in [0.7, 0.79]$.

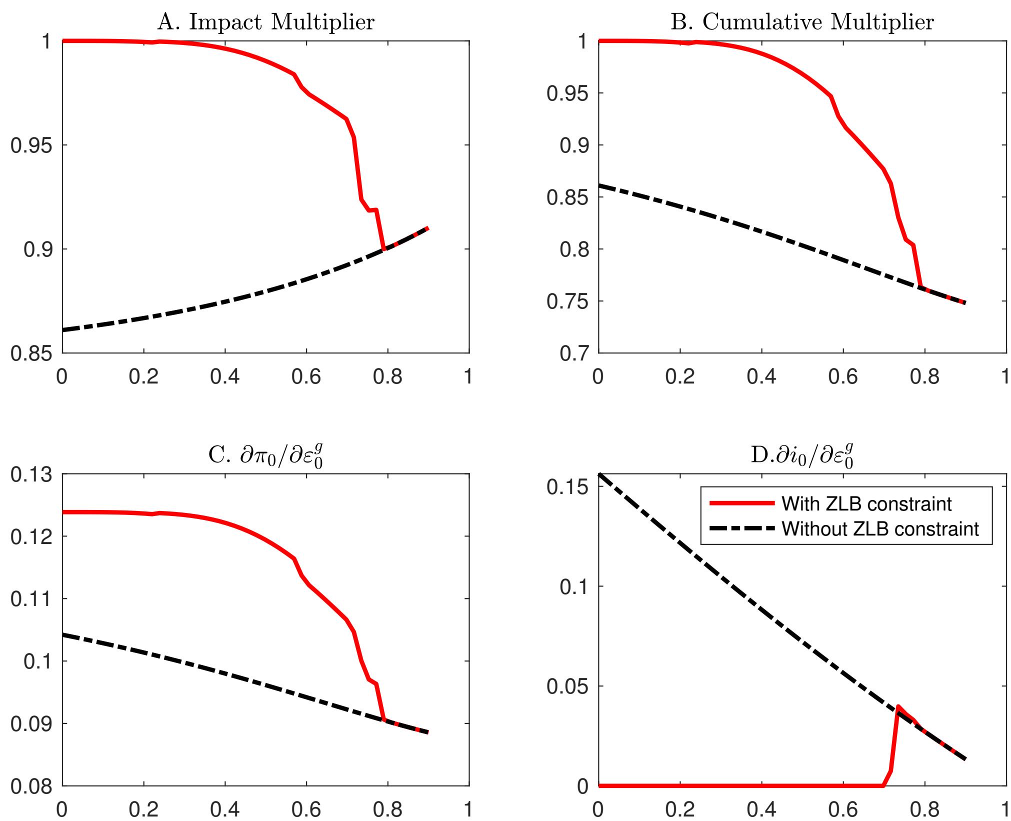

FIGURE 6. Government Spending Multipliers in the Monetary Regime. Note: we set $\phi_\pi = 1.5$ and $\phi_b = 0.0177$ so that the economy is in the monetary regime and 5% of the deviation from target in the debt ratio is corrected over four quarters. Both of the two cases are buffeted by negative natural rate shocks. The red solid line represents the case with ZLB constraint on nominal interest rate, while the black dash line represents the case without ZLB constraint on nominal interest rate.

V.2. **Fiscal Regime.** Now we study the fiscal regime by setting $\phi_\pi = 0.8$ and $\phi_b = 0.0025$. Figure 7 presents the dynamic responses of the economy to the adverse demand shock as in the previous subsection with no fiscal response. Compared with Figure 5 for the monetary regime, we have deflation initially in the fiscal regime, but there is inflation later on before the economy reverts back to zero inflation, even for $\rho = 0$. The intuition can be seen from the present-value government budget constraint (21). Holding everything else constant, initial deflation must be associated with future inflation such that the real value of public debt is equal to the real present value of future surpluses.

Thus, compared with the monetary regime, the duration of the ZLB episode in the fiscal regime is shorter. A negative demand shock generates deflation in the short run, but will generate inflation in the future due to the inflation reversal effect disscussed earlier. The expectation about high future inflation mitigates the initial deflation and reduces the duration of the ZLB episode.

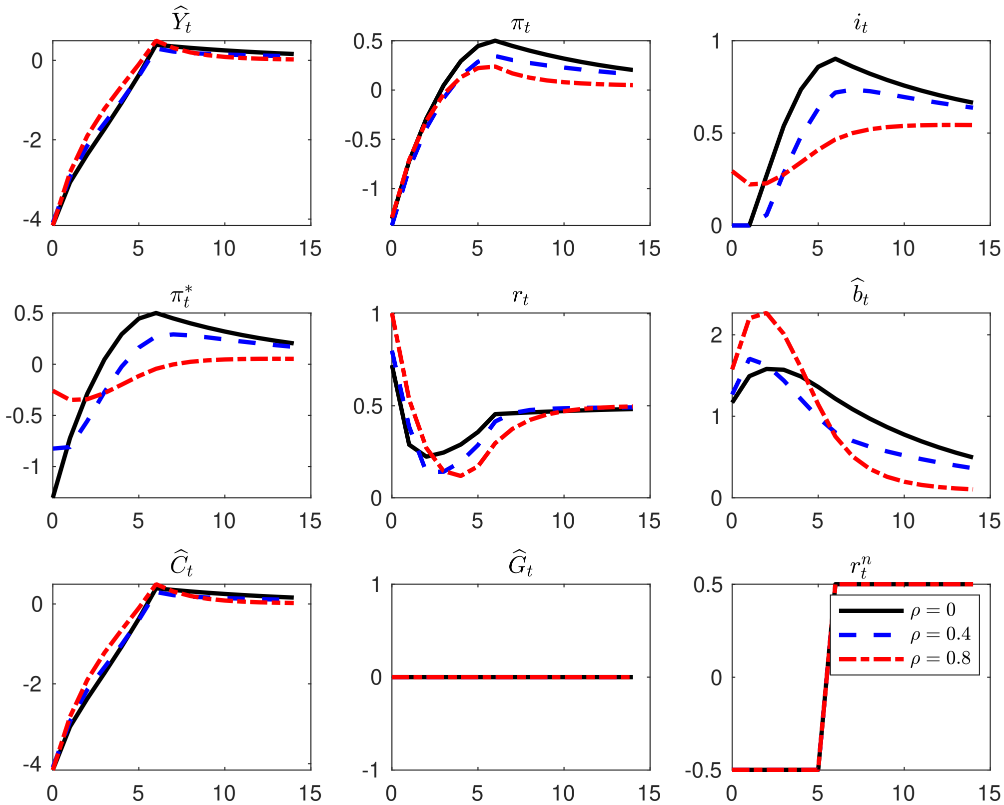

FIGURE 7. Dynamic Effects in the Fiscal Regime without Government Spending: ZLB. Note: we set $\phi_\pi = 1.5$ and $\phi_b = 0.0025$ so that the economy is in the fiscal regime.

As in the monetary regime, the duration of the ZLB episode is not monotonic with ρ. Unlike in the monetary regime, the initial responses of output, consumption, and inflation are not sensitive to changes in ρ.

Next suppose the government raises government spending by 1% of output in the initial period to fight the adverse demand shock. Figure 8 presents the multipliers against ρ. The solid (dashed) lines show the dynamic responses with (without) the ZLB constraint. We find that the impact and cumulative multipliers on output are not monotonic with ρ unlike in the normal times studied in Section 3.3. There are two main reasons: (i) the duration of the

ZLB episode is not monotonic with ρ; and (ii) the initial nominal interest rate response is not monotonic with ρ (see Panel C). When ρ is sufficiently large, the ZLB constraint does not bind and hence the solid and dashed lines overlap.

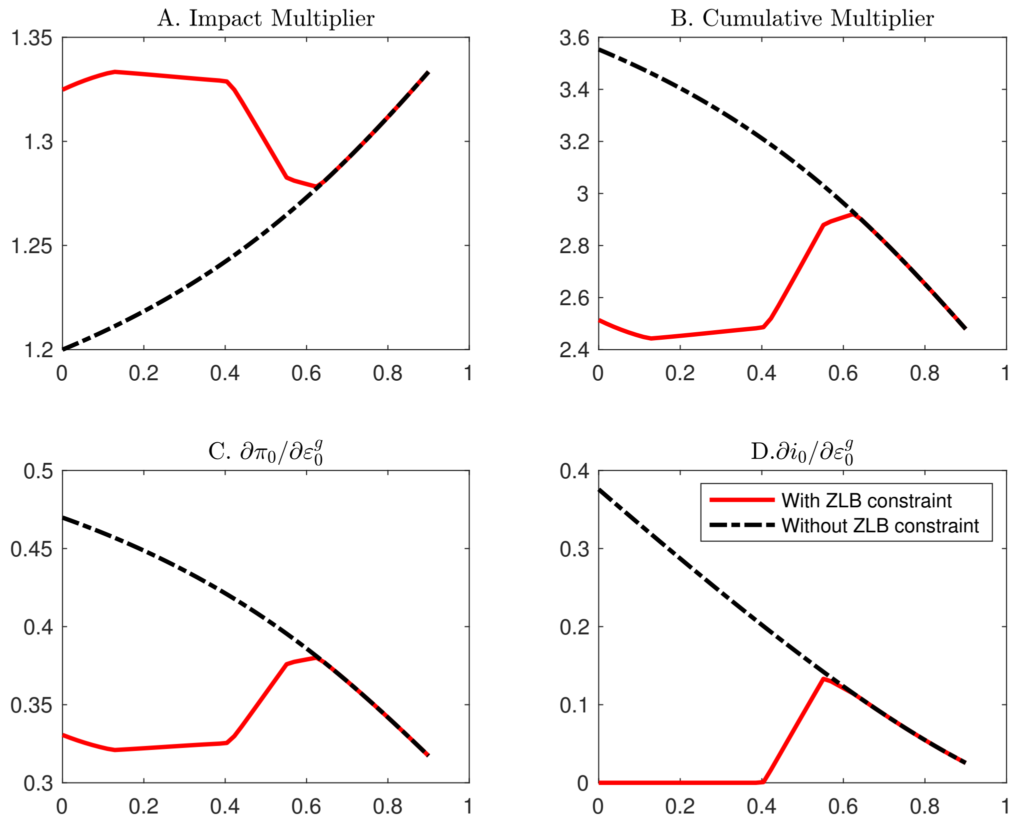

FIGURE 8. Government Spending Multipliers in the Fiscal Regime. Note: we set $\phi_\pi = 0.8$ and $\phi_b = 0.0025$ so that the economy is in the fiscal regime. Both of the two cases are buffeted by negative natural rate shocks. The red solid line represents the case with ZLB constraint on nominal interest rate, while the black dash line represents the case without ZLB constraint on nominal interest rate.

We also find that the cumulative multiplier on output is larger than the impact multiplier, which is larger than 1. As discussed in Section 3 for the normal times, the multiplier in the fiscal regime is typically larger than 1 due to the nominal wealth effect.

V.3. **Duration of Government Spending.** Woodford (2011) and Eggertsson (2010) discuss the importance of the duration of government spending. They argue that the government spending multiplier will be much larger if the stimulus ends after the ZLB ceases to bind. In this subsection we study a different kind of policy experiments. We consider two policies to mitigate the adverse demand shock. For the first policy, the government raises spending by 1% of steady-state output only initially when the shock hits the economy. For the second policy, the government spreads out the 1% spending evenly over the duration of the adverse demand shock.

Figure 9 shows the impact and cumulative multipliers for the monetary regime in which $\phi_\pi = 1.5$ and $\phi_b = 0.0177$. We find the following interesting results. First, for a sufficiently smaller value of ρ, the impact and cumulative multipliers for policy 2 are larger than those for policy 1, which are also larger than 1. Thus spreading out government spending has a larger stimulative effect on the the economy in the monetary regime when ρ is small. The intuition is that a persistent fiscal stimulus only in bad times raises expectations about future inflation and hence reduces the real interest rate at the ZLB. Second, the impact and cumulative multipliers are not monotonic with ρ and also do not change smoothly with ρ. This result is due to the fact that the duration of the ZLB episode is not monotonic with ρ and does not change smoothly with ρ.

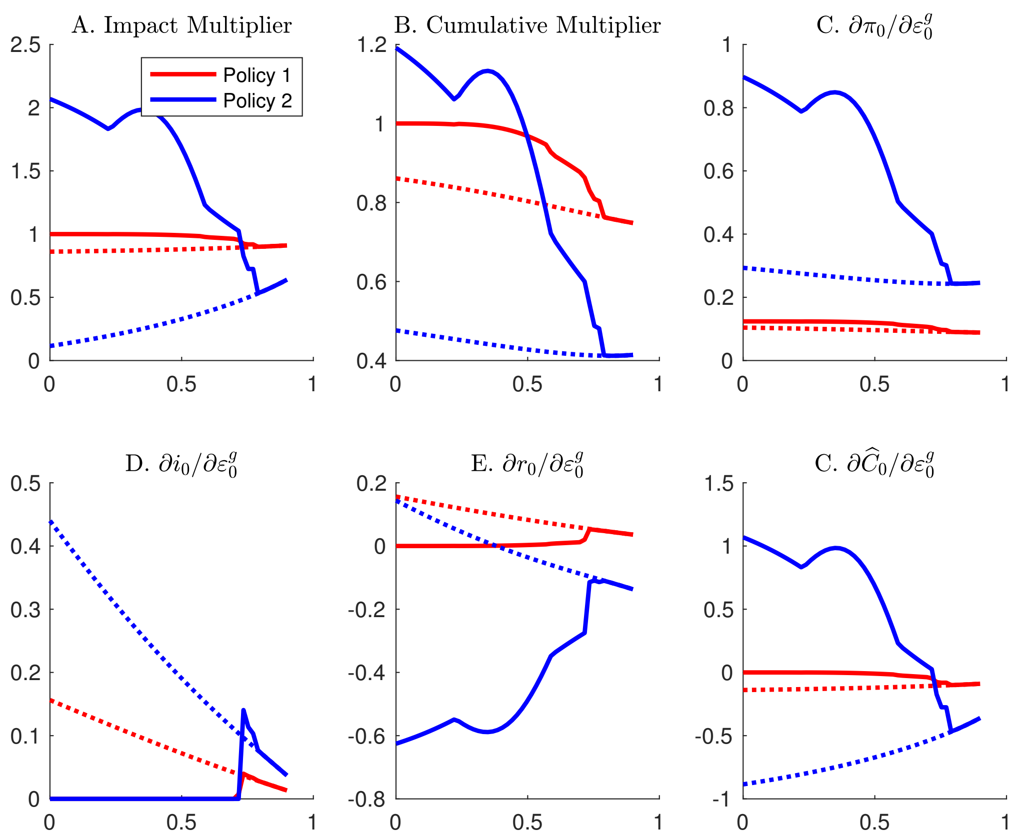

FIGURE 9. Government Spending Multipliers in the Monetary Regime: Duration of Stimulus. Note: The solid lines represent the cases with ZLB constraint on nominal interest rate, while the dotted lines represent the cases without ZLB constraint on nominal interest rate.

Figure 10 shows the multipliers for the fiscal regime in which $\phi_\pi = 0.8$ and $\phi_b = 0.0025$. Unlike in the monetary regime, the impact multiplier is larger for policy 2 than for policy 1, but the cumulative multiplier is smaller for policy 2, for all $\rho \in [0, 1)$. To understand the intuition, we notice that this pattern also holds for the case without the ZLB constraint (dashed lines). As discussed in Section 3.3, the impact of government spending is through the nominal wealth channel. A one-time increase in government spending has a larger wealth effect than an evenly spread increase because the latter has a smaller present value due to discounting. Thus the cumulative multiplier for policy 1 is larger. This result also holds in the presence of the ZLB. By contrast, the impact multiplier for policy 2 is larger because the denominator is 1/6 of that for policy 1.

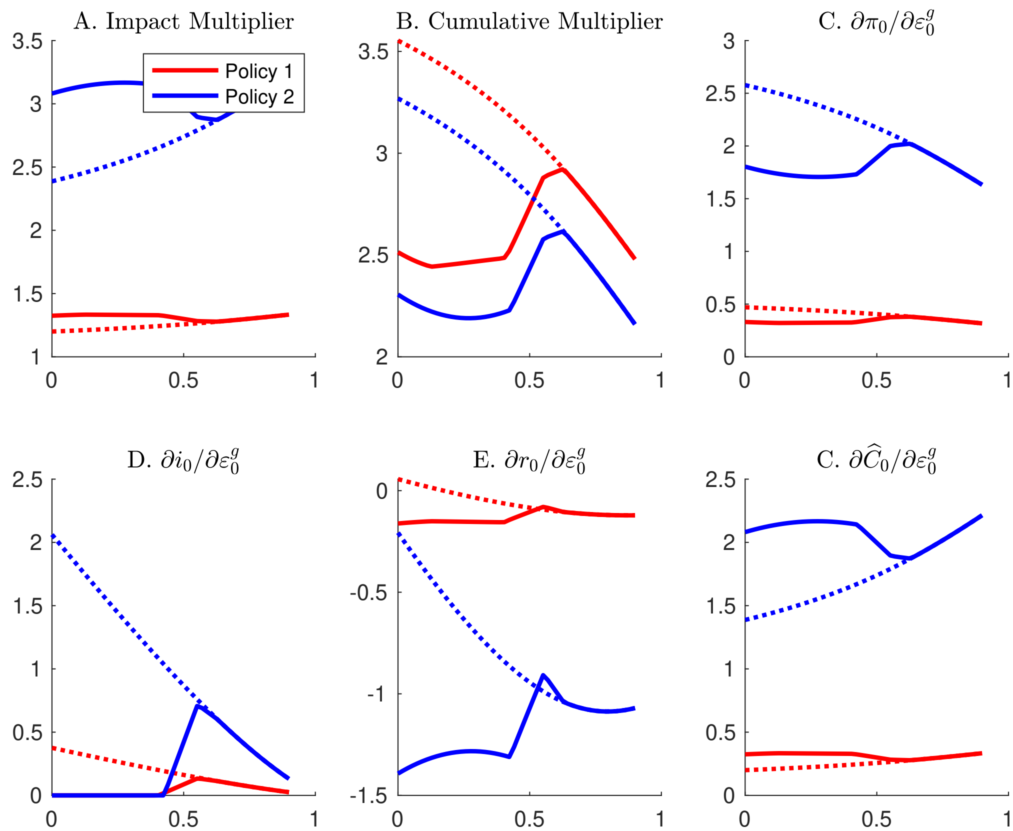

FIGURE 10. Government Spending Multipliers in the Fiscal Regime: Duration of Stimulus. Note: The solid lines represent the cases with ZLB constraint on nominal interest rate, while the dotted lines represent the cases without ZLB constraint on nominal interest rate.

VI. CONCLUSION

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