Government Spending between Active and Passive Monetary Policy*

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Abstract

Conventional wisdom says that the government spending multiplier is larger when monetary policy responds passively (less than one-to-one) to inflation. However, models supporting this consensus fix the monetary policy regime after a government spending shock. This paper proposes a flexible nonlinear SVAR model which allows the central bank to adjust its policy regime in response to future economic conditions after the shock. We find (i) the policy regime changes quickly after the shock and converges rapidly to an active regime if the initial regime was not already active; (ii) little evidence for a multiplier-monetary policy relationship once we account for the endogenous reaction of the policy regime; and (iii) the multiplier at the zero-lower bound exceeds one when we use uncontroversial sign restrictions on impulse response functions for identifying government spending shocks. We conclude that the conventional wisdom is primarily driven by the constant-regime assumption and that the multiplier at the (modern) zero-lower bound is larger than formerly estimated.

Keywords: Fiscal Multiplier, Monetary Policy, Zero Lower Bound, nonlinear SVAR

JEL Codes: C32, E32, E62

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1 Introduction

Does the government spending multiplier depend on monetary policy? Conventional wisdom says that the multiplier is larger when monetary policy is passive.[1,2] We show that this consensus misguides. Models supporting these predictions estimate multipliers leaving the policy rule fixed after a government spending increase. The shortcoming of that approach is that the literature fails to consider how the central bank adjusts its policy regime in response to the economic conditions after the government raised its spending. We demonstrate that the literature – by keeping the policy regime constant after a government spending increase – artificially amplifies differences in the multiplier and overstates the relationship between the multiplier and monetary policy.

This paper proposes a new methodology that allows us to analyze this relationship empirically without constraining monetary policy after a government spending intervention. We estimate a Taylor rule with time-varying coefficients and use its sequence of inflation parameters to inform the monetary policy regimes in a flexible nonlinear SVAR model. This approach lets us discover that (i) the monetary policy regime varies substantially over time and (ii) the central bank changes its policy regime endogenously in response to economic conditions during our sample period. The Fed becomes more active ("hawkish") when inflation is high and more passive ("dovish") during recessions. Accordingly, we allow the central bank to update its policy regime in response to future economic conditions when we estimate the dynamic effects of a government spending shock. We find that the central bank responds quickly after the shock and converges rapidly to an active regime if the initial regime was not already active.

The endogenous response of the monetary policy regime has a fundamental impact on the multiplier. Once we account for the regime's reaction to the government spending shock, we find little evidence for a relationship between the multiplier and monetary policy. In contrast, when we counterfactually keep the policy regime constant after the shock, we find the same result as the theorists have found. Therefore, we conclude that the consensus in

[1] When monetary policy is passive, the central bank raises nominal interest rates less than one-to-to inflation and the real interest rate decreases. The lower real interest rate leads households to increase consumption. Consequently, output increases more than government spending and the multiplier is predicted to be larger than one. In contrast, when monetary policy is active, the central bank responds more than one-to-one to inflation and the multiplier is predicted to be smaller than one.

[2] See e.g., **????????** and **?**.

the literature is primarily driven by the constant-regime assumption – which itself is not a feature of the data – and that the consensus vanishes once we relax this assumption.

The effect of government spending on the economy is a long-lasting research topic in macroeconomics. The core question is whether the government spending multiplier, which measures the change in output in response to a $1 increase in government spending, exceeds one. Despite extensive research, the literature has not reached a final conclusion.[3] However, the literature concurs that monetary policy is a key determinant of the multiplier. Even before the 2008 financial crisis, interactions between government spending and monetary policy were a major policy consideration. Today, governments and central banks work again closely to limit the economic consequences of the Covid-19 pandemic.

Our paper illustrates that the consensus about the relationship between the multiplier and monetary policy hinges on the constant-regime assumption. To reach this conclusion, we make several contributions to the literature. First, we augment the smooth-transition VAR (ST-VAR) model, popularized by **?**, with the Taylor rule. Our approach models the path of monetary policy as an evolving mix of two extreme monetary policy regimes: one when monetary policy is extremely active and another when monetary policy is extremely passive. Following, **??** and **?**, we estimate a Taylor rule with time-varying parameters. Then, we use the estimated series of inflation parameters to inform the evolution of monetary policy in the ST-VAR model. We find that the monetary policy regime evolves continuously over time. That is, monetary policy is not just active or just passive as theory assumes but, instead, varies in more nuanced ways. For instance, in parts of the 1960's and 1970's, the policy regime was neither strongly active nor strongly passive. Furthermore, we find that the central bank changes its policy regime endogenously in response to economic conditions. For example, the Fed raised nominal interest rates aggressively in response to high inflation after Paul Volcker became the chairman of the Fed in August 1979.

Second, we incorporate these features about monetary policy when we estimate the dynamic effects of a government spending shock. When monetary policy itself changes and one wants to understand the impact of a government spending shock, one must consider the initial condition of the shock *and* the consequences for the transitions. These transitions reflect both the direct effect of a shock on the variables and the indirect effect via the future

[3] For theoretical studies, see for example **?????** or **?** and the citations therein. For empirical papers, see for instance **??????** or **?**.

evolution of the monetary policy regime after the shock. First, we divide the initial policy regimes into quintiles and compare multiplier estimates across quintiles. Second, we allow the central bank to adjust its policy regime after the government spending shock.

This exercise reveals that the central bank responds quickly after a shock and transitions rapidly to an active policy if the initial policy was not already “very active”. Then, shortly after the shock and regardless of its initial condition, the central bank reacts actively to inflation. The endogenous response of the policy regime has vital consequences for the multiplier. Once we account for the regime’s reaction to the government spending shock, we find little evidence for a relationship between the multiplier and monetary policy. We argue that the consensus in the literature vanishes because it ignores the response of the policy regime, and, instead keeps the policy regime constant after the shock. However, this theoretical restriction on the policy regime is not a feature of the data, and leads to a misrepresentation about how the multiplier depends on monetary policy.

Third, we identify a government spending shock using sign restrictions on impulse response functions. We define a government spending shock as a shock that drives up output, inflation, government spending, government tax revenue and government debt. These restrictions represent joint predictions of theoretical models, and hence, are relatively uncontroversial. The rest of the empirical literature relies on zero restrictions related to the standard Cholesky approach that have little theoretical foundations (**?**). Regardless of the initial monetary policy regime, our posterior median estimate for the multiplier is around five in the short-run and around one after five years.

We next conduct counterfactual exercises. First, we analyze the multiplier if the central bank were to keep its policy regime temporarily constant after the shock. We motivate this exercise by the observation that the monetary policy regime has been constant during certain subperiods of our sample period. In addition, the bank sometimes announces plans to maintain its current policy for the foreseeable future. We show that the possibility exists that the multiplier may depend on monetary policy but *only* if the central bank were to keep its initial policy regime constant for a surprisingly long period of time after the shock (over two years according to our estimates).

Second, we replicate the framework that underlies the conventional wisdom with our empirical model. To do this, we only distinguish between the two most extreme monetary policy regimes and keep the regimes constant for the entire horizon after the shock. We find that the multiplier is comparable in the short-run but diverges after one year. In the long-run, the multiplier estimates are larger when monetary policy is and remains extremely passive. This result mirrors the consensus in the literature, e.g., **?**. Regardless of whether we only distinguish between active and passive monetary policy or consider a continuum of different regimes, the multiplier diverges if the policy regime remains constant after the shock for a sufficiently long period of time. But because the central bank usually responds quickly after a government spending shock, we conclude that the constant-regime assumption is the key driver of this conventional wisdom – not the data.

Lastly, we analyze the multiplier when nominal interest rates are stuck at zero in response to a severe economic downturn. Between 2008Q4 and 2015Q4, the Fed held nominal interest rates at zero and did not change its policy regime despite unprecedented fiscal policy interventions such as the American Recovery and Reinvestment Act (ARRA). Consequently, we must analyze this era separately from previous monetary policy periods and treat the policy regime at the zero-lower bound as fixed after the shock. Once we identify a government spending shock with our uncontroversial sign restrictions, we find that the multiplier at the zero-lower bound exceeds one. The posterior median estimate is 4.5 on impact and decreases to three after five years. Our estimates are larger than those previously found in the literature, e.g., in **?**. These results suggest that fiscal stimulus packages, such as the ARRA and the CARES act, may have larger economic effects than the literature has formerly concluded.

Literature Our paper relates and contributes to the literature that analyzes the relationship between monetary policy and the government spending multiplier.

First, **???** and **?** consider medium-scale dynamic stochastic general equilibrium (DSGE) models that allow for different fiscal-monetary mixes: active monetary/passive fiscal policy and passive monetary/active fiscal policy. The authors estimate their models for each mix separately and compare the multipliers across mixes.[4] Empirical examples include **?** and **?**. The conventional wisdom says that the multiplier is larger when monetary policy is passive.

[4]**?** is an exception. The authors estimate a DSGE model in which the fiscal-monetary policy mix can change over time. The underlying Markov-Switching approach implies that the policy authorities change their regimes randomly and jump directly from one regime to another. In contrast, we approximate the evolution of the monetary policy regime via an evolving mix between two extreme monetary policy regimes where the transition between regimes is informed by the data. Moreover, our regime changes are not purely random but are based on the inflation parameter from a time-varying Taylor rule. Hence, our method captures the central bank's endogneous reactions to its economic environment.

However, all studies keep the monetary policy (and the fiscal policy) regime constant after the shock. As a result, the central bank itself cannot respond to the changing conditions after a change in government spending. Our method addresses this limitation and allows the central bank to update its policy regime after the shock. We show that the central bank responds quickly after the shock and converges rapidly to an active policy if the initial regime was not already “very active”. Once we account for the reaction of monetary policy, the multiplier's dependence on monetary policy disappears.

Second, we relate to the literature that investigates the multiplier at the zero-lower bound. **?**, **?** and **?** predict that the multiplier exceeds one when monetary policy is constrained by the zero-lower bound. In contrast, **?**, **?**, **?** and **?** argue that the multiplier at the zero-lower bound can be below one. Empirically, **?** and **?** estimate the multiplier at the zero-lower bound during the Great Depression to be around two, while **?** estimate the multiplier at the modern zero-lower bound to be smaller than one. We estimate the multiplier for the modern zero-lower bound era between 2008Q4 and 2015Q4 using a linear VAR model. When we employ the standard Cholesky approach to identify a government spending shock, we find multiplier estimates close to zero which are in line with **?**. In contrast, when we apply our sign restriction approach, the multiplier estimates exceeds one. We argue that the timing restrictions related to the Cholesky approach, as used in **?**, may be violated, especially during this era. The Cholesky approach assumes that governments change their spending in response to shocks to the business cycle only with a delay. However, recent events have demonstrated that governments can react fast during times of crises, see e.g., the CARES act. We show that the identification of government spending shocks matters at the zero-lower bound, and find that the multiplier at the zero-lower bound is larger than the literature currently believes.

Outline Section **??** introduces the methodology. Section **??** describes the evolution of monetary policy in the U.S. Section **??** presents our main results. Section **??** shows our counterfactual analysis. Section **??** includes our zero-lower bound analysis. Finally, section **??** concludes.

2 Model

2.1 Model

This paper studies how the government spending multiplier depends on the responsiveness of monetary policy to inflation. To allow for policy-dependent multipliers, we use the following smooth-transition VAR (ST-VAR) model:

$$X_t = (1 - G(z_{t-1}))\Pi_{AM}X_{t-1} + G(z_{t-1})\Pi_{PM}X_{t-1} + u_t \tag{1}$$

$$u_t \sim N(0, \Omega_t) \tag{2}$$

$$\Omega_t = (1 - G(z_{t-1}))\Omega_{AM} + G(z_{t-1})\Omega_{PM} \tag{3}$$

$$G(z_t) = \frac{1}{1 + exp(\gamma(z_t - c))} \tag{4}$$

where X_t is a vector of endogenous variables that represents the economy. X_t consists of real government spending, real tax receipts, real GDP, Ramey's news shocks, GDP inflation, the federal funds rate and real government debt. We include Ramey's news shock to account for the issue of fiscal foresight.[5,6]

Equation (**??**) says that the economy X_t evolves as a convex combination of two ideal monetary policy regimes. In the AM regime, monetary policy is purely "active" and in the PM regime monetary policy is purely "passive". The transition function $G(\cdot)$ governs the transition between the AM and PM regimes. The state-determining variable z_t characterizes the underlying state of the economy. To describe the evolution of monetary policy over time, we estimate a Taylor rule with time-varying coefficients and use the estimated sequence of the inflation parameter as z_t. This choice allows us to distinguish between different monetary policy regimes for each quarter of our sample period. We provide more details about our choice of z_t in Section **??**. In equation (**??**), u_t is a vector of reduced-form residuals that is assumed to be normally distributed with zero mean and a time-varying covariance matrix

[5] Fiscal foresight arises because changes in fiscal policy are often announced before they are implemented. Hence, agents can react before the policy change is implemented. This creates a misalignment between the information sets of economic agents and the econometrician. As a result, the VAR cannot consistently estimate impulse response functions (**??**). The standard approach to deal with this issue is to include Ramey's news shock to control for agents expectations (**?**). We follow this method.

[6] In Appendix **??**, we conduct a robustness check replacing Ramey's news shock by another measure for agents expectations.

Ω_t. The covariance Ω_t also evolves as a convex combination of the pure regime covariance matrices, Ω_{AM} and Ω_{PM}.

Our ST-VAR model approximates the variation in monetary policy over time as a smoothly-evolving convex combination of the two pure AM and PM regimes. In each period, $G(z_{t-1})$ represents the relative weight on the PM regime and is given by (**??**). We choose $G(z_{t-1})$ to be a logistic sigmoid function, as it is the standard choice in the related literature, see, e.g., **??** or **?**. Equation (**??**) says that $G(z_{t-1})$ is continuous, monotonically decreasing and bounded between zero and one. The transition function $G(z_{t-1})$ depends on the transition parameter γ, the state variable z_t, and on the threshold parameter c. As the variable z_t moves from below c to above c, the value of $G(z_{t-1})$ decreases and the model puts relatively more weight on the AM regime. The rate of this transition between regimes is determined by γ. If $\gamma \approx 0$, then the ST-VAR model collapses to a linear VAR model and no transition occurs. Conversely, if $\gamma \approx \infty$, then the model jumps directly from the PM to AM regime as soon as z_t surpasses c. Thus, the ST-VAR model nests a threshold-VAR model, which also nests Markov-type models. For any value of γ between those two extremes, the transition between the two extreme regimes is smooth.

The literature suggests that monetary policy activism has varied substantially over time, but the nature of that variation is unclear. To allow the data to speak freely, we use fully Bayesian methods to estimate the joint posterior distribution of the model. This approach lets the data to be informative about the model structure – the state-transitioning parameters in particular. This would not be possible when parameters are calibrated. First, we define prior distributions for all model parameters, i.e. $\Pi_{AM}, \Pi_{PM}, \Omega_{AM}, \Omega_{PM}, \gamma$ and c. Second, because the joint posterior distribution is analytically untractable, we employ the multi-move Gibbs sampler proposed by **?** and **?** to let the data update our prior beliefs. The Gibbs sampler partitions the vector of model parameters into different groups. Then, the Gibbs sampler generates draws for each group separately from the corresponding marginal posterior distributions, conditional on the remaining parameters. This procedure simplifies the drawing process because the marginal posterior distributions are often known and easy to sample from. This is an efficient algorithm to generate a Monte-Carlo Markov Chain, as suggested by **?**. Finally, the draws from the marginal posteriors approximate the joint posterior of the model.[7]

[7]See Appendix **??** for a detailed description of our Bayesian Sampler.

In our context, it is crucial that Bayesian methods allow the data to be informative about the transition parameters γ and the threshold parameter c, which in turn inform our beliefs about the evolution of monetary policy. Conditional on the marginal posterior distributions of γ and c, we can compute the posterior distribution of $G(z_{t-1})$ as a function of z_t. Our estimate of $G(z_{t-1})$ captures how monetary policy activism has evolved over time. This exercise reveals that the monetary policy regime behaves differently from how theory models it: Figure **??** illustrates that the monetary policy regime evolves continuously over time, changes smoothly and endogenously in response to inflation and recessions.[8]

2.2 State-determining variable z_t

The key ingredient of the smooth-transition VAR model, equations (**??**) - (**??**), is the state-determining variable z_t. The choice of z_t characterizes the underlying nonlinearity of the economy. Therefore, z_t should embody economically-meaningful and empirically informative attributes of monetary policymakers' behavior. In models similar to ours, the standard approach is to use an observable variable as z_t. For example, **?** and **?** choose the growth rate of real GDP and the unemployment rate, respectively, to replicate the business cycle of the U.S. economy.

Monetary policy is not determined by any single variable, and there is no unique measure of monetary policy activism. However, when theorists make predictions about how the effect of government spending depends on monetary policy, they typically refer to the central bank's responsiveness to inflation as the determinant that distinguishes between the monetary policy regimes (**?**). When monetary policy is active, the central bank raises nominal interest rates more than one-to-one to inflation. As a result, the real interest rate increases and induces households to decrease consumption. Consequently, output increases, but it increases by less than government spending so the government spending multiplier is less than one. When instead monetary policy is passive, the central bank reacts only weakly to inflation and the real interest rate decreases. As a result, households increase consumption, so the government spending multiplier exceeds one. We believe that this measure of policy *responsiveness* likely influences the dynamics of the real economy.

The central bank's responsiveness to changes in inflation is a major theme in both applied

[8]We describe the evolution of monetary policy more detailed in Section **??**.

and theoretical literature. Since **?**, theorists typically use the Taylor rule to model monetary policy. According to the Taylor rule, the central bank sets its policy instrument in response to inflation and output. Because ample evidence exists that monetary policy has changed over time[9], we estimate the following ex-post Taylor rule with time-varying parameters:

$$i_t = c_t + \phi_{\pi,t}\pi_t + \phi_{y,t}y_t + v_t,\ v_t \sim\ N(0, \sigma_t^2) \tag{5}$$

where i_t is the federal funds rate, π_t inflation and y_t is the growth rate of real GDP. c_t is a time-varying constant, and $\phi_{\pi,t}$ and $\phi_{y,t}$ capture the central bank's time-varying responsiveness to inflation and output, respectively. σ_t^2 corresponds to the variance of the residuals that can also vary over time. To allow for permanent and temporary changes in the model coefficients, we assume that $[c_t, \phi_{\pi,t}, \phi_{y,t}]$ and $log(\sigma_t)$ both follow a Random Walk. We then exploit $\phi_{\pi,t}$ to distinguish between different monetary policy regimes in each quarter of our sample period: when $\phi_{\pi,t}$ exceeds one, then the central bank responds more than one-to-one to inflation and the monetary policy regime is *active* in that period. In contrast, if $\phi_{\pi,t}$ is smaller than one, then the central bank responds less than one-to-one to inflation and the monetary policy regime in that period is *passive*.

The model in (**??**) can be written with a state-space representation

$$i_t = \mathbf{z}_t'\phi_t + e_t,\ e_t \sim N(0, \sigma_t^2) \tag{6}$$

$$\phi_t = \phi_{t-1} + v_t,\ v_t \sim N(0, q) \tag{7}$$

$$log(\sigma_t) = log(\sigma_{t-1}) + \eta_t,\ \eta_t \sim N(0, w) \tag{8}$$

where $\mathbf{z}_t = [1, \pi_t, y_t]$ and $\phi_t = [c_t, \phi_{\pi,t}, \phi_{y,t}]$. (**??**) and (**??**) form a linear-Gaussian state-space model, which implies that standard Kalman-filtering techniques can be used to estimate ϕ_t. In contrast, (**??**) and (**??**) build a Gaussian, but nonlinear state-space model. In this case, standard Kalman filtering is not directly applicable. However, **?** and **?** show how the model in (**??**) and (**??**) can be transformed into a linear-Gaussian state-space model so that standard Kalman-filtering techniques can be used to estimate σ_t. We explain the estimation procedure in greater detail in Appendix **??**.

We employ Bayesian methods to estimate (**??**) - (**??**) and then use the median estimate of

[9] See e.g., **??????** or **?**

$\phi_{\pi,t}$ to determine the monetary policy regime for each quarter of our sample period. Therefore, our model is not the standard smooth-transition VAR model as in **?**, but involves a prior step in which we estimate the state variable as a parameter with time-varying coefficients. We refer to our model as smooth-transition VAR model with time-varying parameters or, in short, TVP-ST-VAR model. The TVP-ST-VAR model is preferable to the standard ST-VAR model in situations in which the underlying state of the economy is not well-captured by a single observable variable but can be characterized via a parameter that varies over time.

The estimation of Taylor rules is an interesting topic in the literature. In Appendix **??**, we review the literature and conduct a battery of robustness checks. We now describe the details of our baseline specification of (**??**).

First, we use current inflation and the current growth rate of real GDP as regressors. These choices raise endogeneity concerns (**?**). While, **?** argue that usual instruments such as lagged regressors, real-time data or the **?**'s set of instruments are not fully exogenous if the residuals of the Taylor rule are serially correlated, the resulting bias will be small. **?** estimate the Taylor rule before and after 1980 using OLS and different instruments and uncover comparable estimates. We find that the residuals of our baseline specification are serially correlated, see Appendix **??**. In addition, we find that the estimate of $\phi_{\pi,t}$ of our baseline specification is comparable to those of specifications with lagged regressors, and the set of instruments in **?**. Fortunately, each method captures a similar pattern of variation over time. And because our transition function contains an estimated γ, c, the choice of the state variable is only unique up to an affine transformation.

Second, **???** and **?** advocate using real-time data rather than revised data because revised data may contain information that were not available when policy makers made their monetary policy decisions. Despite their claim, we use revised data in our baseline specification of (**??**). We are more interested in the interaction between policy and the economy, and less interested in how policy decisions were made. For example, a central bank's decision can turn out differently from how it was intended, and this is only visible using revised data. In contrast, real-time data may be more useful in capturing the central bank's intentions. In Appendix **??**, we show that the estimates of $\phi_{\pi,t}$ using revised and real-time data are very similar.

Third, we use the growth rate of real GDP to measure for output rather than the output gap suggested by **?**. This is reasonably common in the literature, as the natural rate of output is not an observable variable and estimates of it are believed to be imprecise. For example, **?** argue that interest rate rules based on output growth are preferable to those that are based on the output gap in models where the natural rate of unemployment is uncertain. **?** shows that loss functions based on output growth rather than the output gap result in lower losses. Finally, **?** illustrate that the Taylor principle breaks down under positive trend inflation, but that it can be restored if the central bank responds to output *growth* rather than the output gap. As explained below, we allow the central bank to adjust its policy regime after the government spending shock. This idea requires us to update the inflation parameter in our forecasts of the real economy. Hence, we must also include all variables of the Taylor rule in the VAR part of our model. Because the impulse response of output is a key ingredient in the formula for the multiplier, we use the growth rate of real GDP as a measure for output in the Taylor rule instead of the output gap.

Finally, the Taylor rule in (**??**) can be contrasted with our model of the economy in (**??**), which also contains an equation for the nominal interest rate. Though the simple Taylor rule is nested in the larger model, the two equations do not embody the same information about the economy. While even simple versions of the Taylor rule have been shown to successfully approximate the central bank's policy instrument, the nominal interest rate equation of (**??**) includes variables that are typically not included in the Taylor rule, e.g. fiscal variables, and several lags of all endogenous variables. In addition, the current response parameters in (**??**) are included in the impact matrix which is not statistically identified. Because the Taylor rule is the most widely accepted way to model policy activism, we choose $\phi_{\pi,t}$ from (**??**) as the state variable that distinguishes between different monetary policy regimes in our analysis. This choice ensures that we capture a recognizable component of "true" monetary policy behavior while we avoid imposing any additional restrictions on the overall economy in (**??**).

2.3 Generalized Impulse Response Functions

In nonlinear models such as ours, impulse responses depend on the shock's sign, size and the timing of the shock. In addition, the state of the economy can respond to economic conditions – both during the sample period and after shocks. If one wants to understand how the impact of a government spending shock depends on monetary policy and monetary policy itself changes, one must consider the initial state of the economy and the dynamics that arise from both the direct effect of a shock on the variables and its *indirect* effect via the future evolution of the monetary policy rule in response to economic conditions after the shock.

To incorporate these features, we follow **?** and employ generalized impulse response functions. Generalized IRFs are defined as the expected difference between two simulated paths of the economy. Formally, they can be written as

$$\begin{aligned} GIRF(h) = \; & E[(1-G(z_{t+h-1}))\Pi_A \hat{X}^{\epsilon}_{t+h-1} + G(z_{t+h-1})\Pi_P \hat{X}^{\epsilon}_{t+h-1} + \epsilon_{t+h}] \\ & - E[(1-G(z_{t+h-1}))\Pi_A \hat{X}^{u}_{t+h-1} + G(z_{t+h-1})\Pi_P \hat{X}^{u}_{t+h-1} + u_{t+h}]. \end{aligned} \tag{9}$$

The first part of (**??**) represents the simulated path of the economy hit by a government spending shock, $\hat{X}^{\epsilon}_{t+h}$. The second part corresponds to the simulated path when the economy is *not* hit by the government spending shock, $\hat{X}^{u}_{t+h}$.

The generalized IRFs require initial conditions from a starting period. Given a particular starting period, we use (**??**) to roll the model forward in both simulations. Thus, we can estimate the effects of a government spending shock for each monetary policy regime by choosing starting conditions that correspond to a particular policy. Later, we divide the monetary policy regimes into quintiles to distinguish between different monetary policy regimes, e.g., between "very active", "weakly active", "neutral", "weakly passive" and "very passive" regimes. Then, we draw randomly the initial conditions from these quintiles and present the average difference between two simulations as in (**??**) for each quintile.

2.4 Updating Rules for Monetary Policy

In nonlinear models such as our TVP-ST-VAR model, the state of the economy can respond to its economic environment, such as in response to shocks. In section **??**, we see that the central bank changes its monetary policy regime frequently in response to inflation and recessions. The generalized impulse response functions also allow for scenarios in which the underlying state of the economy changes after the shock. Based on the forecasts for the economies with and without a government spending shock, X^{ϵ}_{t+h} and X^{u}_{t+h}, we can also forecast the corresponding values of z_{t+h} and then of $G(z_{t+h})$. The new values of $G(z_{t+h})$

and $1 - G(z_{t+h})$ represent the weights assigned towards to purely active and purely passive monetary policy h periods after the shock. The updated weights then enter the forecasts of the economies with and without the government spending shock in the next periods, X^{ϵ}_{t+h+1} and X^{u}_{t+h+1}. Hence, the monetary policy regime can change after the government spending shock and further affect how the government spending shock disseminates through the economy.

To implement this feature, we run the Kalman filter as described in Section **??** based on the forecasted values of the federal funds rate, inflation and output growth. Each time we predict the economy one step ahead, the Kalman filter obtains a new $\phi_{\pi,t+h}$ and $\phi_{y,t+h}$ which represent the central bank's responsiveness to inflation and output growth, respectively, for that period. At each step, we use that estimate of $\phi_{\pi,t+h}$ as z_{t+h} and plug it into the transition function to update the weights of the two monetary policy regimes. This method requires the Taylor rule to use the same information set as the rest of our model. We believe that our model is the most intuitive approach: we discuss some other possibilities in Appendix **??**.[10] These updating rules can only reflect average behavior according to the historical data: the Federal Reserve relies on its own discretion when updating its policy.

2.5 Identification

Identification of structural shocks in our nonlinear model is similar to identification in linear models. The reduced form errors, u_t, do not have an economic interpretation. Macroeconomic theory assumes that the reduced form errors are linear combinations of structural shocks ϵ_t. Formally,

$$u_t = A\epsilon_t, \tag{10}$$

where

$$A = Chol(\Omega_t)Q. \tag{11}$$

[10] For example, we can also run a regression of the forecasted values of the federal funds rate on the forecasted values on inflation and output growth, and use the point estimate of the inflation parameter, $\hat{\phi}_{\pi,t+h}$, as z_{t+h}. Additionally, we can update $\hat{\phi}_{\pi,t+h}$ via an AR(1) process in which we pre-define the persistence parameter.

$Chol(\Omega_t)$ is the Cholesky decomposition of the covariance matrix Ω_t, and Q is an orthogonal matrix, $QQ' = I$. The matrix A is not identified statistically: to identify the structural shocks, we must impose economically meaningful restrictions on A.

We identify government spending shocks using sign restrictions on impulse response functions. This strategy has been used in the literature by **??** and **?**. We follow **?** and define a government spending shock as a shock that drives up output, inflation, government spending, government tax revenue and government debt. This set of restrictions is consistent with a large set of neoclassical and new Keynesian models (**?**). In this study, we assume that this set of restrictions holds regardless of the monetary policy regime.

The sign restriction strategy has major advantages over other methodologies. First, the imposed restrictions are derived from theoretical models. Our restrictions represent joint predictions of theoretical models and are therefore relatively uncontroversial. Furthermore, sign restrictions impose only very weak restrictions on the behavior of the economy, as we only restrict the signs of certain impulse responses. Finally, sign restrictions allow all variables to contemporaneously react to all shocks while other strategies, e.g., the recursive approach, impose specific timing restrictions that govern which variables can react to the shocks on impact. Sign restrictions in linear VAR models have been widely applied and are well documented; e.g. see **?** for an overview. **?** implement sign restrictions on generalized impulse response functions and we follow their approach.[11]

3 History of Monetary Policy

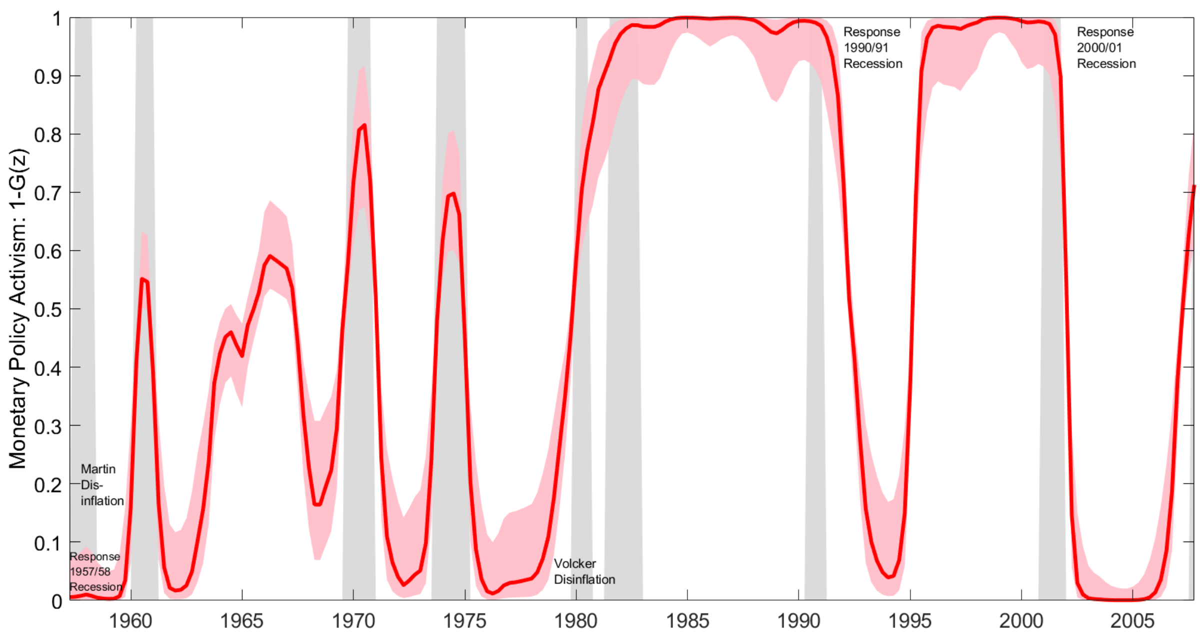
In this section, we describe how monetary policy has evolved over our sample period. We are using quarterly data for the U.S. economy from 1954Q3 to 2007Q4. In Section **??**, we extend the sample period to 2015Q4 to include the zero-lower bound epoch. Figure **??** plots the median estimate of $1-G(z_{t-1})$, the weight assigned to the purely active monetary policy regime, along with the 68 percent credible bands. We interpret $1-G(z_{t-1})$ as a measure of the central bank's activism because larger values of $1-G(z_{t-1})$ occur when the central bank responds more strongly to inflation. Low values of $1-G(z_{t-1})$ indicate a more "passive" monetary policy regime.

Figure **??** reveals that the monetary policy regime varies substantially over time. Policy

[11] Details are provided in Appendix **??**.

was very passive during the second half of the 1950s, while the model puts additional weight to the purely active monetary policy regime during the 1960s. In the 1970s, the monetary policy regime is very passive, only interrupted by the summer of 1970 and the winter of 1974/75. Consistent with the existing narrative in the literature, monetary policy changes dramatically when Paul Volcker became the chairman of the Federal Reserve. Between 1979 and 1982, monetary policy transitioned from a very passive regime to a very active regime, and remained very active throughout the 1980s. During the first half of the 1990s, our model assigns a low weight to the active regime, while it assigns a relatively high weight to the active regime during the second half. Since 2000, monetary policy has been mostly passive, save for the very end of our sample period.

Figure 1: Evolution of Monetary Policy between 1954 and 2008



Note: Figure shows the median of the posterior distribution of $1 - G(z)$, along with the 68 percent credible bands. Grey bars represent NBER recessions. The figure shows that monetary policy is not best described by two extreme regimes, changes smoothly and has responded several times to both inflation and recessions.

Our results regarding $1 - G(z_{t-1})$ lend support to existing narrative evidence given by **?**. **?** describe how monetary policy was very passive during the late 1950's before the Federal Reserve increased nominal interest rates in response to high inflation in 1959 (Martin Disinflation). Moreover, **?** illustrate that the Fed ran a very passive monetary policy throughout most of the 1970s, only interrupted in 1970 and in the winter of 1974/75. Subsequently, the Fed raised nominal interest rates in response to high inflation: this occurred around the time of Paul Volcker's appointment in August 1979 (Volcker Disinflation). In addition, **?** characterize the chairmanships of Paul Volcker (1979-1987) and Alan Greenspan (1987-2006) as periods in which the Fed responded actively to inflation. These periods were only interrupted during the first half of the 1990s and 2000s, when the Fed lowered nominal interest rates in response to the 1990/91 and 2000/01 recessions. Finally, **?** argues that the Fed deviated substantially from the Taylor principle between 2002 and 2005. Our estimates in Figure **??** support this argument as well. Between 2002 and 2005, $1 - G(z_{t-1})$ reaches its lowest value of the entire sample period. Appendix **??** contains a more detailed timeline of monetary policy in the United States.

The posterior of $1 - G(z_t)$, shown over time in Figure **??**, also sheds some light on the theoretical frameworks in the literature, which only distinguish between active and passive monetary policy. Common models assume that monetary policy rules do not change in response to conditions such as inflation or recessions–or government spending shocks. Some studies fix the policy rule, while others, e.g., **?**, use the Markov Switching approach to model policy changes as purely random. That method implies that the central bank jumps randomly from one regime directly to another.

Figure **??** provides evidence that the monetary policy regime evolves differently from these models. First, monetary policy is not well described by the two extreme regimes, but rather by a process that evolves continuously over time. For example, during the second half of 1950s and in the late 1960s, the monetary policy regime is characterized by two different degrees of passiveness. Similarly, in 1970 and throughout the 1980s, the policy regime exhibits two different degrees of activeness. This observation implies that even within the active and the passive regime, there are still differences in terms of active and passive monetary policy can be.

Second, Figure **??** suggests that when monetary policy changes, it changes smoothly rather than abruptly. For example, the change in the monetary policy regime around 1980 took three years. The data does not seem to prefer an extremely large γ parameter, casting doubt on the Markov-switching approaches. This result supports **?** and **?** who reach similar conclusions that monetary policy evolves smoothly.

Finally, our estimates of monetary policy and the narrative evidence given by **?** demonstrate that the central bank has changed its policies several times to economic conditions during our sample period. For example, the Fed increased nominal interest rates aggressively (and became extremely active) in response to high inflation in 1959 and 1979 - 1982. Similarly, the Fed lowered nominal interest rates (and became more passive) in response to the recessions of 1957/58, 1990/91 and 2000/01. These observations suggest that impulse response functions that fix the Taylor Rule after the government spending shock might be misplaced, rendering their conclusions suspect.

Taken together, these observations guide our approach to estimate the government spending multiplier conditional on the monetary policy regime in what follows. Most importantly, we observe that the central bank *does* change its policy endogenously in response to economic conditions. Next, we ask whether the evolution of monetary policy can be affected by government spending shocks. Our main model allows for the possibility that the central bank adjusts its policy regime in response to future economic conditions after the shock, e.g., the central bank can switch to a more active policy when inflation grows large after a government spending increase. In the next section, we explore how the assumption of a constant policy rule may influence how our modeled economy evolves after government spending shocks.

4 Results

This section presents our main results. We estimate our TVP-ST-VAR model using quarterly data for the U.S. economy from 1954Q3 to 2007Q4. The sample excludes the period in which monetary policy in the U.S. and other countries was constrained by the zero-lower bound. This cutoff is often applied in the literature to avoid contamination through the effects of the Great Recession and unconventional monetary policy, e.g., **?** or **?**. More importantly, though, the Fed kept nominal interest rates at zero between 2008Q4 and 2015Q4. This says that despite massive fiscal policy interventions such as the American Recovery and Reinvestment Act (ARRA) or the Troubled Asset Relief Program (TARP), the Fed did not respond to economic conditions during this period.[12] Finally, we estimate our model with fully Bayesian methods that also include the marginal posterior distributions of γ and c.

[12]We analyze the government spending multiplier at the zero-lower bound in Section **??**.

We then employ generalized impulse response functions to estimate the dynamic effects of a government spending shock. The generalized IRFs require an initial condition that allows us to estimate the multiplier for each initial monetary policy regime of our sample period. For comparison, we divide the initial regimes into quintiles and compare the multipliers when monetary policy is initially "very active", "weakly active", "neutral", "weakly passive" or "very passive" according to the value of $G(z_{t-1})$ during the impact period. If the conventional wisdom is correct, we expect to see increasing multiplier estimates as we move smoothly from the most active quintile towards the most passive quintile. Finally, the generalized IRFs allow the central bank to change its policy regime in response to the government spending shock. For instance, the central bank can switch to a more active policy if inflation grows large after the shock.

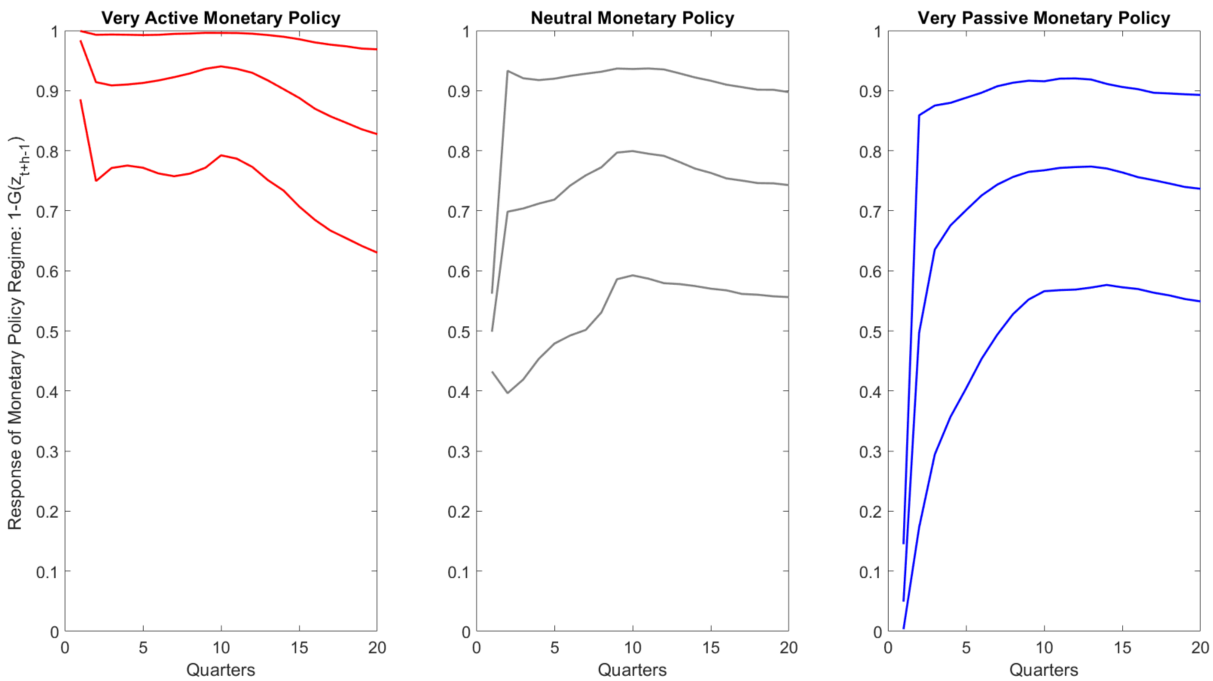
To estimate the multiplier, we follow **?** and use the formula for the *sum* multiplier

$$\Phi_h = \frac{\sum_h^{j=0} y_j}{\sum_h^{j=0} g_j} \times \frac{\bar{Y}}{G}, \tag{12}$$

where y_j and g_j are the responses of output and government spending, respectively, in period j after the government spending shock. $\frac{\bar{Y}}{G}$ is the sample mean of the output-to-government spending ratio. Using the sum-formula, we estimate the multiplier for different time horizons after the shock.

Figure **??** displays the response of the monetary policy regime after the government spending shock if the monetary policy regime is initially "very active", "neutral" and "very passive" using the evolution of $1 - G(z_{t-1})$. The figure reveals interesting results: when the monetary policy regime is initially "very active" (left subplot), the central bank does not adjust its responsiveness to inflation very much. The bank remains in the active sphere of the monetary policy spectrum for the entire horizon after the shock. In contrast, if the monetary policy regime is initially "neutral" or "very passive", then the central bank responds quickly and transitions fast to a more active regime. Thus, shortly after the shock, the central bank – regardless of its initial regime – conducts policy in more or less the same way and responds actively to inflation. This result implies that the common practice of keeping the monetary policy regime constant after the shock is misplaced, *especially* for passive regimes. A natural question to ask is whether the endogenous response of the monetary policy regime affects the government spending multiplier. It does: Figure **??** shows the multipliers as a function

Figure 2: Response of the Monetary Policy Regime to a Government Spending Shock



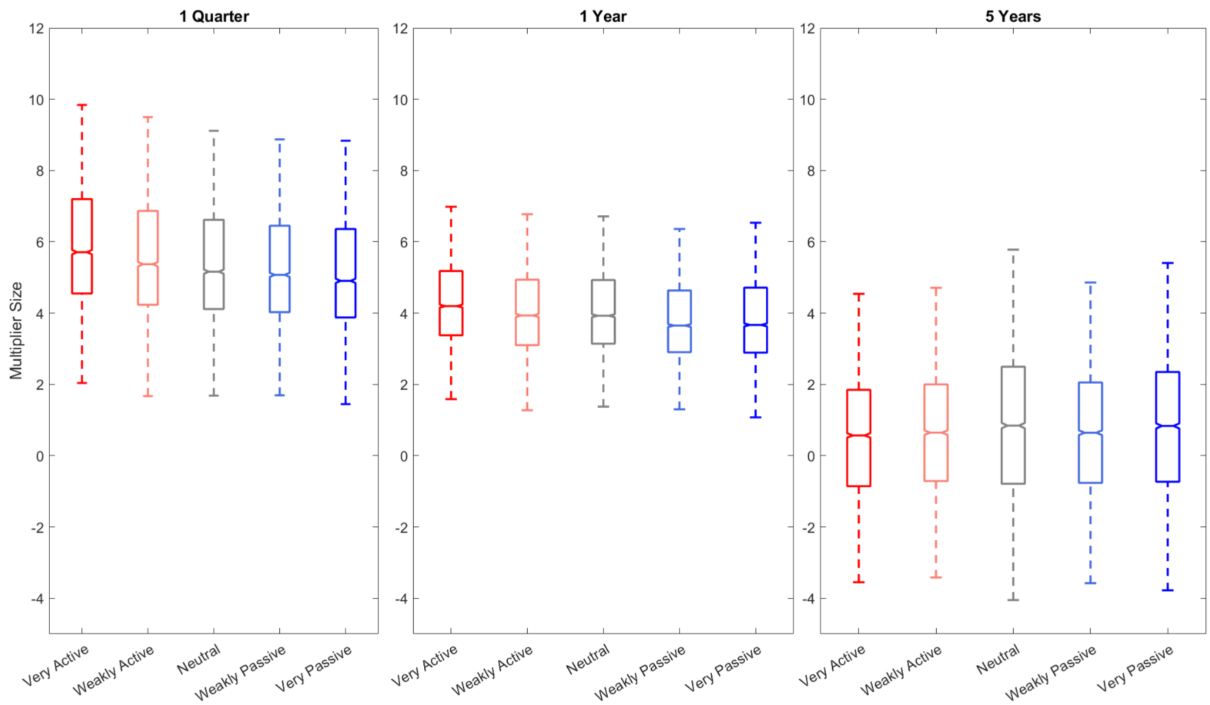
Note: Figure shows the evolution of $1-G$ in response to a government spending shock when monetary policy is initially "very active", "neutral" and "very passive". The central bank responds quickly and transitions rapidly to an active policy when the initial policy is not already active. Shortly after the shock and regardless of its initial condition, the central bank responds actively to inflation.

of the initial regime.[13]

Figure **??** compares the distributions of the government spending multiplier across the initial monetary policy regimes using boxplots. If the consensus in the literature holds, then, after accounting for the endogenous response of the monetary policy regime, the boxplots *should* shift upwards for the more passive regimes. However, Figure **??** shows that there is little variation in the boxplots in a given time period after the shock. One quarter after the shock, the posterior median is around five regardless of the initial regime. One year after the shock, the posterior median is around four. Five years after the shock, the posterior median is around one while the distributions are not entirely positive. Thus, we find that

[13]The results in the figure differ from those in theory; such as in **?**. But we can replicate the theoretical consensus by restricting monetary policy to remain constant after a fiscal shock: this result appears in detail in Section **??**.

Figure 3: Multiplier when monetary policy regime is continuous and fully endogenous

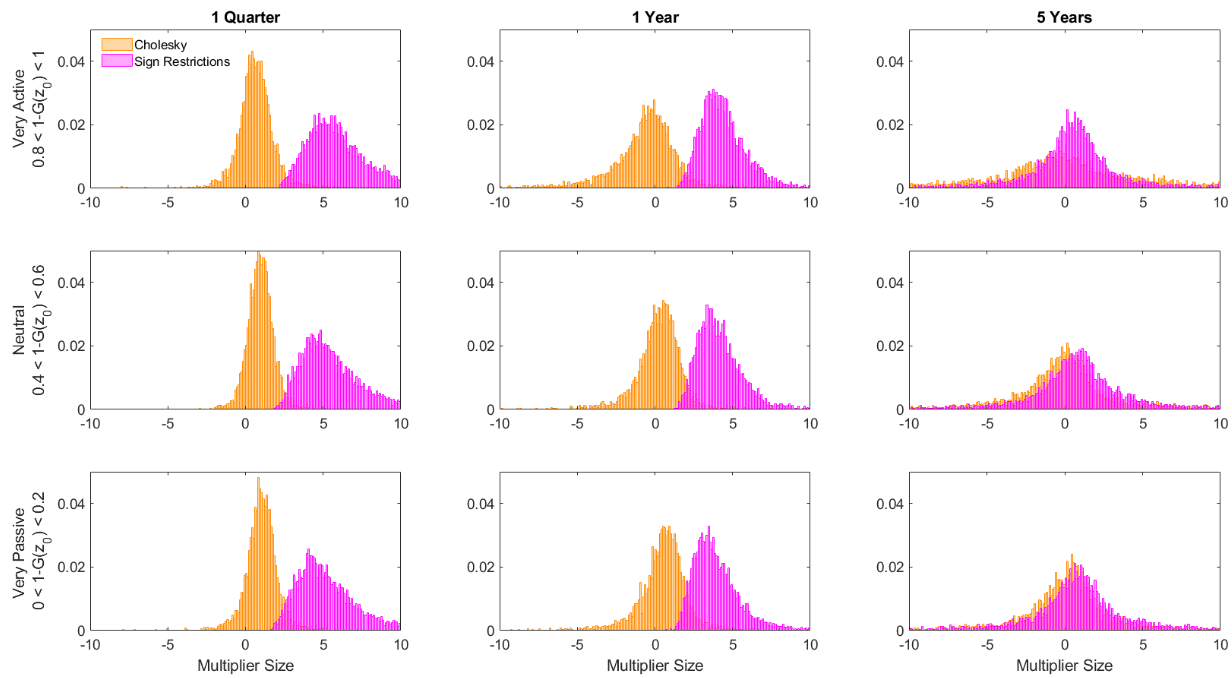


Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. The Figure suggests that the multiplier decreases over time but is unrelated to the initial monetary policy regime.

the multiplier decreases in magnitude over time, but this decrease does not seem to depend on the initial monetary policy regime as the literature has concurred.

The results given in Figure **??** suggest that multiplier estimates in the short-run are considerably larger than in the long-run. The empirical government spending literature largely agrees that the multiplier lies between 0.3 and 2.1 (**??**). However, the multiplier can also be negative (**?**) and as high as 3.5 (**?**). Our estimated short- and medium-run multiplier estimates are considerably larger. However, the literature has either only focused on longer-run multipliers and/or has employed identification strategies related to the Cholesky approach in which government spending is ordered first in a recursive VAR. This method imposes zero restrictions and requires one to assume that governments adjust their spending in response to shocks other than to government spending only with a delay.

Figure 4: Multiplier Comparison: Recursive Identification vs. Sign Restriction Approach



Note: Comparison of recursive (orange) and sign restricted (violet) multiplier estimates for the "very active", "neutral" and "very passive" monetary policy regime. Multipliers are similar after five years but differ in the short- and medium-run. Results suggest that once one considers multipliers in the short- and medium-run and replaces questionable timing restrictions with theoretically-justified sign restrictions, multiplier estimates can be larger than previously conjectured in literature.

In Figure **??**, we compare the multiplier estimates from our main exercise (violet histograms) to those using the Cholesky approach (orange histograms). We find smaller estimates in the short-, and the medium-run for the Cholesky approach. The estimates are similar after five years. The comparison of multiplier estimates using different identification approaches is an important exercise. The findings indicate that once we consider multipliers in the short- and medium-run and replace the zero restrictions with little theoretical foundations related to the recursive approach with our sign restrictions that are relatively uncontroversial, the multiplier may be larger than previously conjectured in the literature.

The results of this exercise contradict the conventional wisdom that the government spending multiplier is larger when monetary policy is passive. Our findings suggest that the multiplier does not depend on monetary policy, either in the short-run or in the long-run. This largely reflects the fact that the central bank adjusts its policy quickly after the shock and converges to a more active regime if the initial regime was not already "very active". The consensus in the literature does not take this endogenous response of the monetary policy regime to the government spending shock into account. Because the result hinges on a model assumption that lacks empirical support, and vanishes once that assumption is relaxed, we must conclude that the consensus (that fiscal multipliers are larger when monetary policy is passive) is artificial and *not* a feature of the data. We next provide additional evidence that the constant-regime assumption is the key factor underlying the conventional wisdom.

5 Counterfactuals

Because our main results contradict the theoretical consensus, we conduct a counterfactual analysis. First, we analyze what would happen to the government spending multiplier if the central bank were to keep its monetary policy regime temporarily constant after the shock. Second, we fully replicate the framework that underlies the consensus in the literature with our empirical model. To do this, we only distinguish between the purely active and the purely passive monetary policy regimes, and keep the monetary policy regime constant for the entire horizon after the shock. These exercises suggest that the constant-regime assumption drives the result in the theoretical literature.

Because the policymaker *can* commit to a policy rule for an extended period of time, these contingencies represent hypothetical policy scenarios.

5.1 Government Spending Multiplier under temporary constant Monetary Policy

In Section **??**, we found that the central bank adjusted its monetary policy regime immediately after the government spending shock when the regime was not already "very active". However, the central bank can also choose to maintain its policy of the impact period for some specific time after the shock. In fact, the monetary policy regime *is* nearly constant during certain subperiods of our sample period. For instance, in Figure **??**, the monetary policy regime is purely active throughout the 1980s and the second half of the 1990s. In contrast, the monetary policy regime is purely passive in the second half of the 1970s and the first half of the 2000s. Sometimes, the central bank also signals its intentions to hold policy constant in the future. For example, on April 29^{th}, 2020, the Federal Reserve announced:

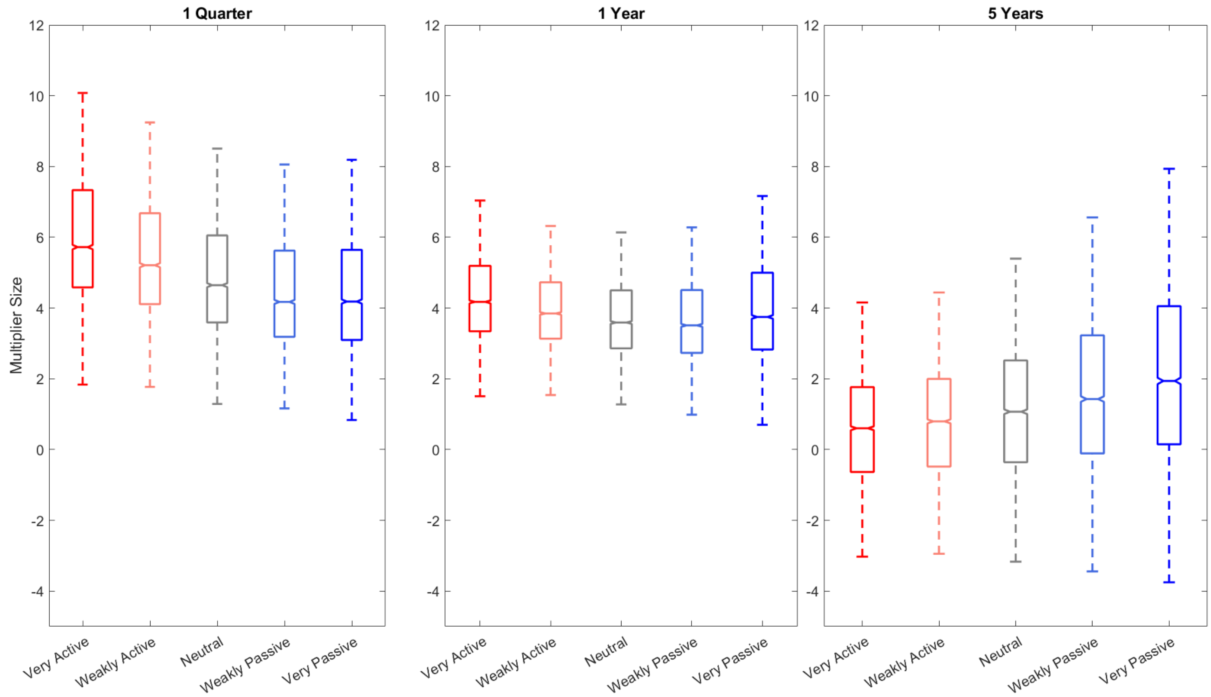
> "The ongoing public health crisis will weigh heavily on economic activity, employment, and inflation in the near term, and poses considerable risks to the economic outlook over the medium term. In light of these developments, the Committee decided to maintain the target range for the federal funds rate at 0 to 1/4 percent. The Committee expects to maintain this target range until it is confident that the economy has weathered recent events and is on track to achieve its maximum employment and price stability goals."[14]

Hence, we address this possibility directly. First, we analyze what would happen to the government spending multiplier if the central bank were to keep its policy temporarily constant after the government spending shock. To do this, we employ the generalized impulse response functions but keep the inflation parameter $\phi_{\pi,t+h}$ constant for one, two and five years. After these periods expire, we continue as before by updating $\phi_{\pi,t+h}$ via the "rolling" Kalman filter for each period h of the forecast horizon. Figures **??** and **??** display the corresponding multiplier estimates when the monetary policy regime is restricted to remain in its initial regime for one and five years after the shock, respectively.

If the central bank keeps its policy regime constant for one year after the shock, the results are similar to those in Section **??**. The government spending multiplier decreases in magnitude over time, but it does not vary significantly with the initial monetary policy regime. We find similar results if we keep the monetary policy regime constant for two years.[15] In contrast, when the central bank keeps its policy regime constant for five years after the shock, we do observe a higher multiplier estimate in more passive regimes after five years. This is in line with the conventional wisdom and indicates that there exists a possibility that the government spending multiplier may depend on monetary policy. However, the difference in the multiplier hinges on the central bank's willingness to maintain the policy regime for extended periods of time. According to our analysis, the central bank must maintain its

[14] Source: `https://www.federalreserve.gov/newsevents/pressreleases/monetary20200429a.htm`
[15] Results are available upon request.

Figure 5: Estimated Multipliers if Monetary Policy is Constant For One Year



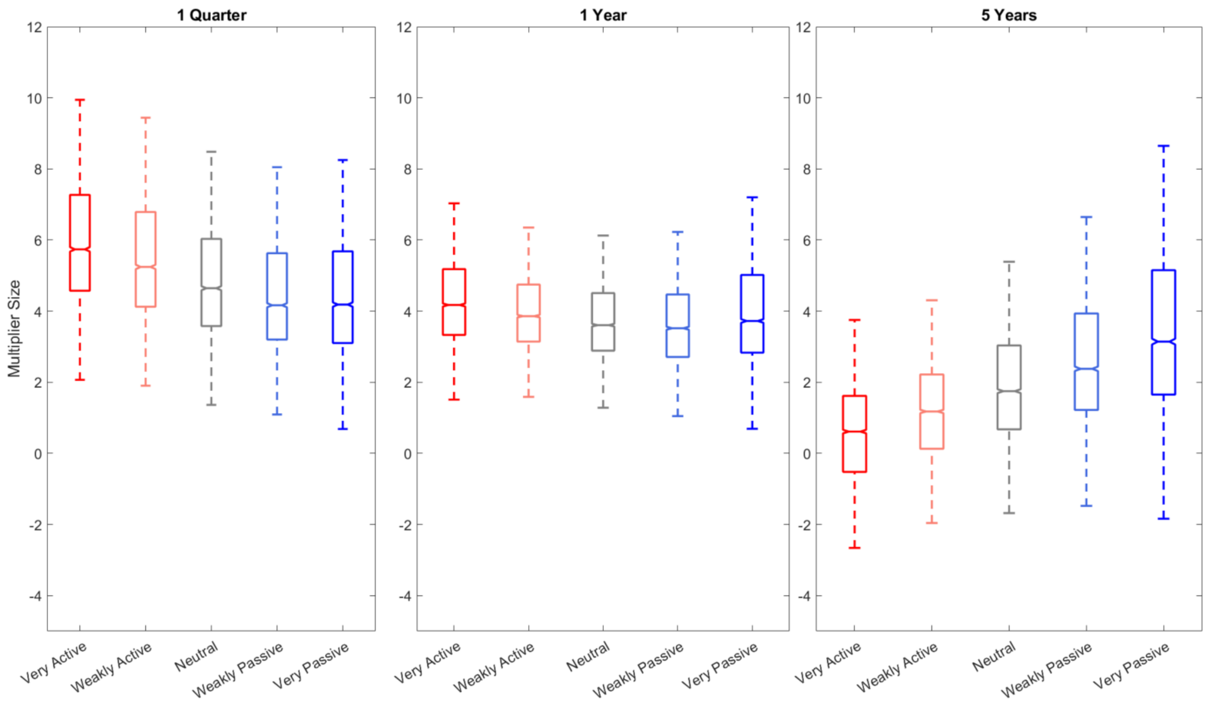
Note: Figure shows the estimated multiplier distributions across initial monetary policy regimes when the regime is kept constant for one year after the shock using boxplots. The middle line and the box present the posterior median and 50 percent credible bands of the corresponding distribution. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. The Figure suggests that the multiplier decreases over time but is unrelated to the initial monetary policy regime even if the regime is held constant for one year.

initial policy rule for more than two years before one can discern any noticeable difference in the government spending multiplier with respect to monetary policy.

5.2 Government Spending Multiplier under fully constant Monetary policy regimes

We now "replicate" the theoretical framework with our empirical model. Recall that theory interprets monetary policy as binary and only distinguishes between "active" and "passive" monetary policy regimes. In addition, some studies use the Markov Switching approach to model policy changes, which implies that the central bank jumps from one monetary policy

Figure 6: Estimated Multipliers if Monetary Policy is constant for five years



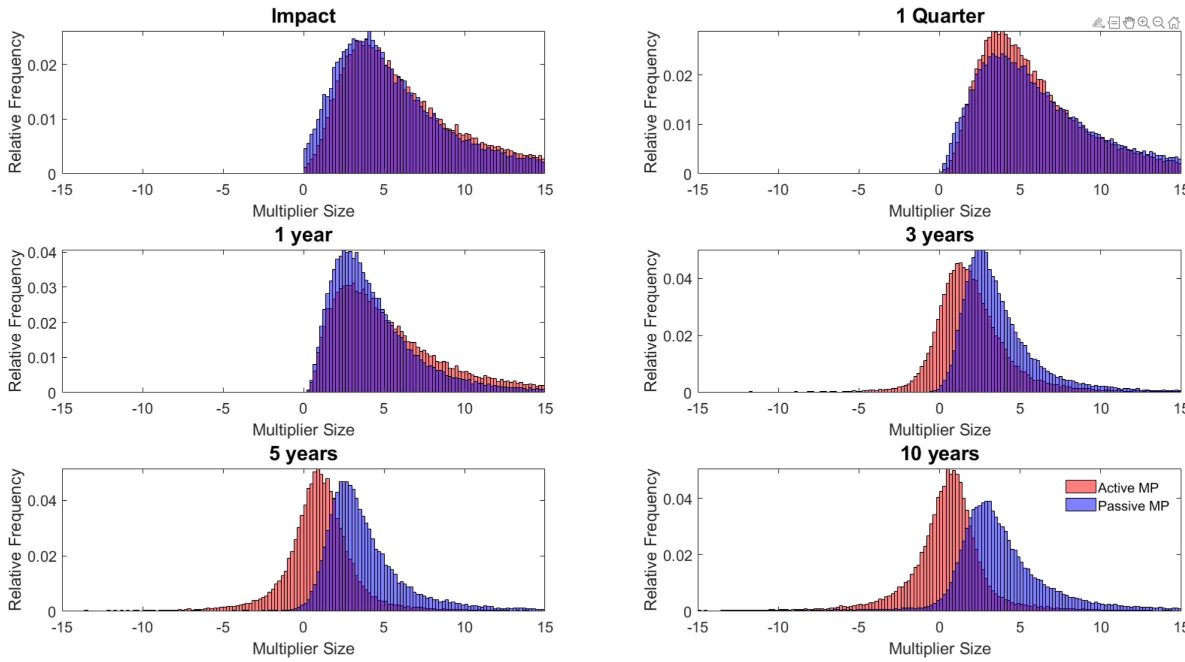
Note: Figure shows the estimated multiplier distributions across initial monetary policy regimes when the regime is kept constant for five years after the shock using boxplots. The middle line and the box present the posterior median and 50 percent credible bands of the corresponding distribution. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. The Figure suggests that the multiplier is larger for the more passive regimes in the long-run if the regime is held constant for five years.

regime directly to another. Lastly, theory treats the monetary policy regime constant for the entire time after the shock when they compute impulse response functions.

To implement the same framework, we estimate the TVP-ST-VAR model with an exogenous γ that we calibrate to be very large. This choice ensures that the central bank jumps randomly from one regime directly to another. We then use traditional impulse response functions to estimate the dynamic effects of the shock. The traditional impulse response functions estimate the effects for the purely active (AM) and the purely passive (PM) regime, rather than an interior combination. Finally, the traditional IRFs keep the regimes constant for the entire forecasted horizon after the shock. Figure **??** presents the results.

Figure **??** illustrates that if we replicate the theoretical framework with our empirical

Figure 7: Multiplier Estimates in Model with binary and fixed Monetary Policy



Note: Figure shows the multiplier distributions for the most active and most passive regime when the regimes are kept constant for the entire time after the shock. The results confirm the theoretical consensus in the literature and mirror the predictions provided in **?**. Findings also uncover assumptions that are necessary to "match" conventional wisdom.

model, then we can replicate the theoretical consensus. Up to one year after the shock, the distributions of the multiplier highly overlap so that there is no meaningful difference in the estimated multiplier between the two most extreme monetary policy regimes. One year after the shock, the multiplier starts to diverge. In the long-run, the multiplier is estimated to be higher when monetary policy is and remains purely passive. This evidence matches the theoretical consensus, and mirrors the results in **?** who find comparable multipliers in the short-run but a higher multiplier under passive monetary policy in the long-run. We also obtain similar results when we conduct the same analysis, but estimate the full posterior distribution of model including an estimated γ, instead of setting γ exogenously equal to a large number, see Figure **??**.

Because we find regime-dependent multipliers *only when we restrict the monetary policy* *regime to remain unchanged* as in these two exercises, we conclude the conventional wisdom in the literature is largely driven by that constant-regime assumption. Regardless of whether we interpret monetary policy as a continuous or a binary process, or whether changes in the policy regime are smooth or abrupt, the government spending multiplier diverges in the long-run only if we keep the monetary policy regime constant for at least two years. When we relax this assumption and allow the central bank to respond freely after the shock, the multipliers ceased to diverge.

6 Government Spending Multiplier at the Zero-Lower Bound

We now estimate the government spending multiplier at the zero-lower bound (ZLB). Our previous analysis truncates the data sample in 2007Q4 to avoid contaminating findings with the Great Recession and its unconventional monetary policy. More importantly, though, the Fed kept nominal interest rates at zero between 2008Q4 and 2015Q4. Consequently, the Fed did not change its policy regime during this period, despite large fiscal policy interventions such as the TARP and the ARRA. Currently, major central banks again cut nominal interest rates to zero. Recent announcements by the Federal Reserve to keep interest rates low even if inflation exceeds its fixed target of two percent lets as expect that nominal interest rates will remain at zero in the foreseeable future, at least in the United States. These circumstances require us to analyze the multiplier at the ZLB separately from previous monetary policy regimes and keep the policy regime constant after the shock. Therefore, we use traditional instead of generalized impulse response functions in this section.

There is substantial interest in the size of the government spending multiplier when monetary policy is constrained by the zero-lower bound (ZLB). This question has been at the center of policy debates since the Financial crisis when central banks around the world cut nominal interest rates until they hit zero. Despite achieving "liftoff" from the zero-lower bound in 2015Q4, the Federal Reserve cut nominal interest rates again to zero in March 2020 to limit the economic consequences of the Coronavirus pandemic. The zero-lower bound remains a major concern in many other economies at this time.

This issue has also been the subject of a fast growing body of literature. Theory provides opposing predictions. On the one hand, **?**, **?** and **?** predict that the government spending multiplier is higher when monetary policy accommodates inflation, and is especially high when monetary policy is constrained by the ZLB. However, this belief has been challenged by **?**, **?**, **?** and **?** who argue that the multiplier at the ZLB can be below one. The disagreement leaves the question to empiricists for adjudication.

However, empirical studies reach different conclusions as well. **?** and **?** find multipliers above two for the ZLB period during the Great Depression. In contrast, **?** and **?** provide evidence that the government spending multiplier at the (modern) ZLB is below one.

In this section, we conduct several exercises to analyze the government spending multiplier at the ZLB. First, we estimate our TVP-ST-VAR model for an extended sample period up to 2015Q4 in order to include the ZLB. The federal funds rate is stuck at zero between 2008Q4 and 2015Q4, which prevents us from extracting useful information during that period (**?**). Hence, we follow **?** and replace the federal funds rate during the ZLB by the shadow rate.[16] Second, we estimate a linear VAR for the period between 2008Q4 and 2015Q4 and compare the multiplier estimates with those from a version of our replication exercise in Section **??** where we estimate the full posterior of the TVP-ST-VAR model, including the posterior of γ and c.

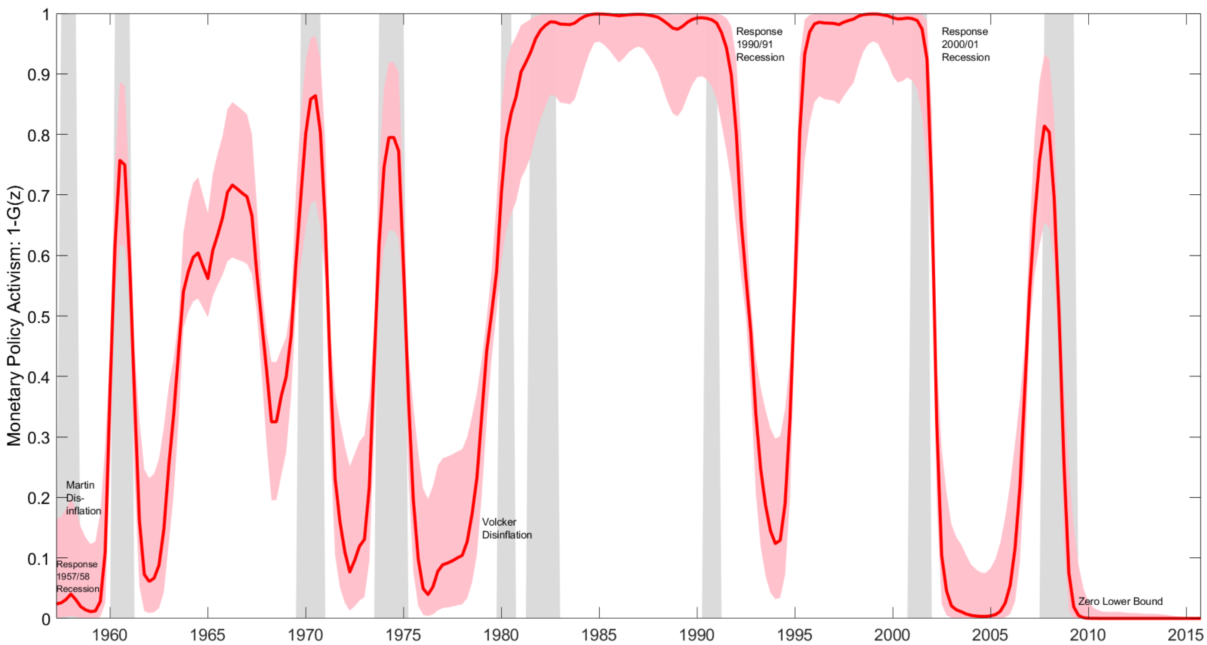
Figure **??** displays the evolution of the monetary policy regime for the extended sample period. We can see that $1 - G(z_{t-1})$ is zero between 2009 and the end of the sample with very little uncertainty. This observation suggests that the zero-lower bound is a very passive monetary policy regime. This assessment supports the "crowding-in" argument proposed by **?**, **?** and **?** that the government spending multiplier should be particularly large at the ZLB because the central bank does not respond to inflation which lowers the real interest rate, and households raise consumption. However, if we compare the multiplier between the purely active and the purely passive regime, we find that the distributions highly overlap in the short- and long-run, which contradicts the divergence result from Figure **??**.[17] Were the ZLB truly a purely passive regime, we would expect the corresponding multiplier to be larger than the multiplier from the purely active regime. Hence, we conclude the modern ZLB in the United States does not correspond to a purely passive regime: it is likely characterized

[16]**?** estimate the shadow rate using a Shadow rate term structure model in which the shadow rate is a linear combination of latent factors. The factors are extracted from a set of one-month forward rates. See **?** for an overview.

[17]Results are available upon request.

by other unexplored factors.

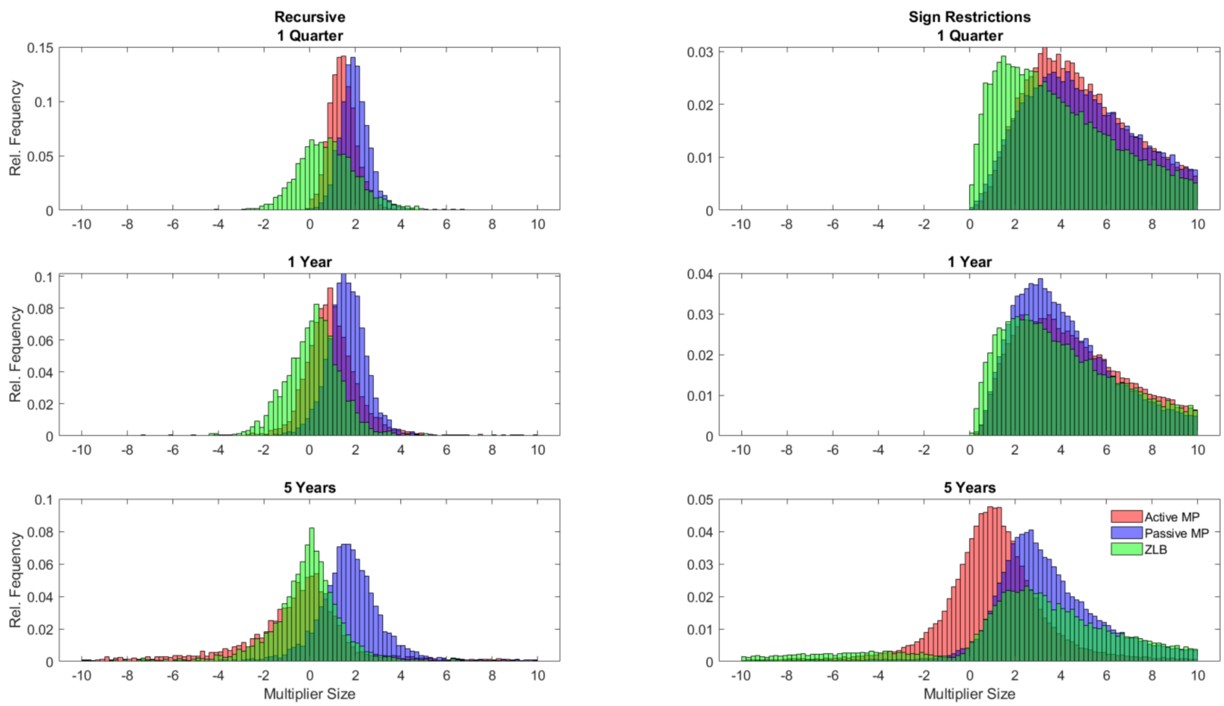
Figure 8: Evolution of Monetary Policy between 1954 and 2016 with Shadow Rate



Note: Figure shows the median of the posterior distribution of $1 - G$, along with the 68 percent credible bands and the evolution of the real interest rate as black line. The grey bar represents the NBER recessions. During the ZLB (2009-2016), $1 - G$ is consistently zero with very little uncertainty.

To illustrate further, we estimate a linear VAR model for the ZLB period and compare the multiplier to those from the purely active and purely passive regimes when we estimate the full posterior of our baseline TVP-ST-VAR model. Figure **??** displays the results. The related literature uses a variety of identification strategies, so we report both Cholesky and Sign Restricted multipliers. In the left column of Figure **??**, we identify the government spending shock using the Cholesky method. Following **?**, we order government spending first in a recursive VAR. In the right column, we apply our sign restriction approach. When we identify the government spending shock using the recursive approach, we find that the government spending multiplier at the ZLB is very small, similar to the multiplier under the purely active monetary policy regime. Regardless of the forcast horizon, the distribution is centered around zero. Hence, the multiplier at the ZLB may not even be positive. This result is in line with **?** and **?** who also find small multipliers at the ZLB. In contrast, when we identify the government spending shock using our sign restriction approach, we find that the multiplier is large and similar to the multiplier under the purely passive monetary policy regime.

Figure 9: Multiplier Estimates at the Zero-Lower Bound



Note: Figure shows the distribution of the multiplier at the zero-lower bound (green) and when the monetary policy regime is and remains purely active (red) and purely passive (blue) after the shock. Using the recursive identification strategy, the multiplier at the zero lower bound is centered around zero. However, when we employ the sign restrictions approach, the multiplier at the zero-lower bound is mostly positive even after the restricted horizon and larger than previously estimated.

These comparisons between the multipliers at the ZLB using different identification strategies yield interesting insights. Using the recursive approach, the multiplier is smaller than the estimate when we employ our sign restrictions approach (even after taking the estimation uncertainty into account). Ordering government spending first in a recursive VAR implies that governments can change their spending plans in response to shocks other than a government spending shock only with a delay. This was once a popular approach. However, these Cholesky timing restrictions may be violated in the modern world – especially during periods in which the central bank is constrained by the ZLB. The Coronavirus Aid, Relief, and Economic Security Act (CARES) of 2020 represents the largest economic stimulus package of any kind in U.S. history, and was debated and passed into law in only a few weeks. The Paycheck Protection Program (PPP) attached to that package disbursed \$349 billion in less than two weeks. The Troubled Asset Relief Program (TARP) of 2008 similarly disbursed hundreds of billions in the same quarter as the bill was passed by congress – suggesting that governments *can* react fast during times of crises so that the timing restrictions related to the recursive approach are violated in the current era.

In contrast, our imposed set of sign restrictions is consistent with a large class of neoclassical and new Keynesian models, and hence, has theoretical foundations. These sign restrictions also allow government spending to respond quickly, as in the CARES, PPP, and TARP examples. Given this additional evidence, we conclude that the multiplier at the ZLB is larger than previous estimates in the literature. For the period between 2008Q4 and 2015Q4, Our median multiplier estimate is 4.5 on impact and three after five years.

7 Conclusion

This paper develops a flexible nonlinear SVAR model to investigate the relationship between the government spending multiplier and monetary policy. Conventional wisdom says that the multiplier is larger when the central bank reacts passively to inflation. However, models supporting this consensus keep the monetary policy regime constant after the government spending shock. Hence, the literature ignores how the *central bank* adjusts its policy regime in response to the economic conditions after a change in government spending. As a result, the literature artificially amplifies the differences in the estimated multipliers. Our approach relaxes this assumption and allows the central bank to update its policy regime after a government spending intervention.

Our analysis shows that the central bank responds quickly after the shock and converges fast to an active regime if the initial regime was not already active. The endogenous response of the policy regime has vital implications for the multiplier: once we account for the reaction of the policy regime, the consensus in the literature vanishes. In contrast, when we keep the policy regime constant after the shock, we find estimates that support the conventional wisdom. Because this theoretical restriction on the policy regime has only little empirical support, we conclude that it is constant-regime assumption that is the key driver of the conventional wisdom – not the data.

Furthermore, we analyze the multiplier at the zero-lower bound. In particular, we compare the multiplier estimates from different identification strategies. When we use the standard Cholesky approach for identifying government spending shocks, we find multiplier estimates near zero. In contrast, when we apply our sign restriction method, the multiplier estimates exceed one. We argue that the timing restrictions related to the Cholesky approach may be violated, especially at the zero-lower bound. This scheme implies that governments react to changes in the business cycle only with a delay. However, the TARP of 2008 and the CARES act of 2020 have demonstrated in a dramatic way that governments can react fast during times of crises, e.g., when nominal interest rates are cut to zero in response to a severe economic downturn.

Our analysis highlights the necessity of accounting for the reaction of monetary policy to the government spending shock in order to properly study the relationship between monetary policy and the multiplier. Failure do so forces us ignore the central bank's ability to respond to the shock and leads to a misrepresentation about how the multiplier depends on monetary policy. We also show that the identification of government spending shocks matters when monetary policy is constrained by the zero-lower bound. Once we employ relatively uncontroversial sign restrictions on impulse response functions for identification, the multiplier is larger than previously estimated in the literature. This result suggests that fiscal stimulus packages, such as the ARRA and the CARES act, may have have larger economic effects than the literature has formerly concluded.

References

S. R. Aiyagari, L. J. Christiano, and M. Eichenbaum. The output, employment, and interest rate effects of government consumption. *Journal of Monetary Economics*, 30(1):73–86, 1992.

M. Almunia, A. Benetrix, B. Eichengreen, K. H. O'Rourke, and G. Rua. From great depression to great credit crisis: similarities, differences and lessons. *Economic policy*, 25(62): 219–265, 2010.

J. E. Arias, D. Caldara, and J. F. Rubio-Ramirez. The systematic component of monetary policy in svars: An agnostic identification procedure. *Journal of Monetary Economics*, 101:1–13, 2019.

S. B. Aruoba and F. Schorfheide. Macroeconomic dynamics near the zlb: A tale of two equilibria. 2013.

A. J. Auerbach and Y. Gorodnichenko. Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, 4(2):1–27, 2012.

C. Baumeister and J. D. Hamilton. Inference in structural vector autoregressions when the identifying assumptions are not fully believed: Re-evaluating the role of monetary policy in economic fluctuations. *Journal of Monetary Economics*, 100:48–65, 2018.

M. Baxter and R. G. King. Fiscal policy in general equilibrium. *The American Economic Review*, pages 315–334, 1993.

N. Ben Zeev and E. Pappa. Chronicle of a war foretold: The macroeconomic effects of anticipated defence spending shocks. *The Economic Journal*, 127(603):1568–1597, 2017.

F. Bianchi and C. Ilut. Monetary/fiscal policy mix and agents' beliefs. *Review of economic Dynamics*, 26:113–139, 2017.

O. Blanchard and R. Perotti. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *The Quarterly Journal of Economics*, 117 (4):1329–1368, 2002. doi: 10.1162/003355302320935043.

J. Boivin. Has us monetary policy changed? evidence from drifting coefficients and real-time data. *Journal of Money, Credit and Banking*, 38(5 (August 2006)):1149–1174, 2006.

G. Caggiano, E. Castelnuovo, V. Colombo, and G. Nodari. Estimating fiscal multipliers: News from a non-linear world. *The Economic Journal*, 125(584):746–776, 2015.

F. Canova and E. Pappa. Fiscal policy, pricing frictions and monetary accommodation. *Economic Policy*, 26(68):555–598, 2011.

C. K. Carter and R. Kohn. On gibbs sampling for state space models. *Biometrika*, 81(3): 541–553, 1994.

C. Carvalho, F. Nechio, and T. Tristao. Taylor rule estimation by ols. *Available at SSRN 3265449*, 2019.

Y. Chang and B. Kwak. Us monetary-fiscal regime changes in the presence of endogenous feedback in policy rules. 2017.

V. Chernozhukov and H. Hong. An MCMC approach to classical estimation. *Journal of Econometrics*, 115(2):293–346, 2003.

S. Chib and E. Greenberg. Understanding the metropolis-hastings algorithm. *The american statistician*, 49(4):327–335, 1995.

L. Christiano, M. Eichenbaum, and S. Rebelo. When is the government spending multiplier large? *Journal of Political Economy*, 119(1):78–121, 2011.

R. Clarida, J. Gali, and M. Gertler. Monetary policy rules and macroeconomic stability: evidence and some theory. *The Quarterly journal of economics*, 115(1):147–180, 2000.

J. S. Cloyne, Ò. Jordà, and A. M. Taylor. Decomposing the fiscal multiplier. Technical report, National Bureau of Economic Research, 2020.

T. Cogley and T. J. Sargent. Evolving post-world war ii us inflation dynamics. *NBER macroeconomics annual*, 16:331–373, 2001.

T. Cogley and T. J. Sargent. Drifts and volatilities: monetary policies and outcomes in the post wwii us. *Review of Economic dynamics*, 8(2):262–302, 2005.

O. Coibion and Y. Gorodnichenko. Monetary policy, trend inflation, and the great moderation: An alternative interpretation. *American Economic Review*, 101(1):341–70, 2011.

T. Davig and E. M. Leeper. Monetary–fiscal policy interactions and fiscal stimulus. *European Economic Review*, 55(2):211–227, 2011.

C. de Vries and W. Li. Estimating monetary policy rules with serially correlated monetary policy shocks. *Unpublished manuscript*, 2013.

B. Dupor and R. Li. The expected inflation channel of government spending in the postwar us. *European Economic Review*, 74:36–56, 2015.

W. Edelberg, M. Eichenbaum, and J. D. Fisher. Understanding the effects of a shock to government purchases. *Review of Economic Dynamics*, 2(1):166–206, 1999.

G. B. Eggertsson. What fiscal policy is effective at zero interest rates? *NBER Macroeconomics Annual*, 25(1):59–112, 2011.

A. Ellahie and G. Ricco. Government purchases reloaded: Informational insufficiency and heterogeneity in fiscal VARs. *Journal of Monetary Economics*, 90:13–27, 2017. doi: 10.1016/j.jmoneco.2017.06.002.

A. Fatás and I. Mihov. The effects of fiscal policy on consumption and employment: theory and evidence. 2001.

M. Forni and L. Gambetti. Sufficient information in structural vars. *Journal of Monetary Economics*, 66:124–136, 2014.

S. Frühwirth-Schnatter. Data augmentation and dynamic linear models. *Journal of time series analysis*, 15(2):183–202, 1994.

J. Galí, J. D. López-Salido, and J. Vallés. Understanding the effects of government spending on consumption. *Journal of the european economic association*, 5(1):227–270, 2007.

A. B. Galvão and M. T. Owyang. Financial stress regimes and the macroeconomy. *Journal of Money, Credit and Banking*, 50(7):1479–1505, 2018.

D. Gefang and R. Strachan. Nonlinear Impacts of International Business Cycles on the UK–A Bayesian Smooth Transition VAR Approach. *Studies in Nonlinear Dynamics and Econometrics*, 14(1), 2010.

R. J. Gordon and R. Krenn. The end of the great depression 1939-41: Policy contributions and fiscal multipliers. Technical report, National Bureau of Economic Research, 2010.

M. T. Kiley. Policy paradoxes in the new keynesian model. *Review of Economic Dynamics*, 21:1–15, 2016.

S. Kim. Structural shocks and the fiscal theory of the price level in the sticky price model. *Macroeconomic Dynamics*, 7(5):759–782, 2003.

S. Kim, N. Shephard, and S. Chib. Stochastic volatility: likelihood inference and comparison with arch models. *The review of economic studies*, 65(3):361–393, 1998.

G. Koop, M. H. Pesaran, and S. M. Potter. Impulse response analysis in nonlinear multivariate models. *Journal of econometrics*, 74(1):119–147, 1996.

S. Laumer. Government spending and heterogeneous consumption dynamics. *Journal of Economic Dynamics and Control*, page 103868, 2020.

S. Laumer and C. Philipps. Does the government spending multiplier depend on the business cycle? 2020.

E. M. Leeper, T. B. Walker, and S.-C. S. Yang. Fiscal foresight and information flows. *Econometrica*, 81(3):1115–1145, 2013.

E. M. Leeper, N. Traum, and T. B. Walker. Clearing up the fiscal multiplier morass. *American Economic Review*, 107(8):2409–54, 2017.

L. Linnemann and A. Schabert. Productive government expenditure in monetary business cycle models. *Scottish Journal of Political Economy*, 53(1):28–46, 2006.

M. Lippi and L. Reichlin. The dynamic effects of aggregate demand and supply disturbances: Comment. *The American Economic Review*, 83(3):644–652, 1993.

K. R. Mertens and M. O. Ravn. Fiscal policy in an expectations-driven liquidity trap. *The Review of Economic Studies*, 81(4):1637–1667, 2014.

W. Miyamoto, T. L. Nguyen, and D. Sergeyev. Government spending multipliers under the zero lower bound: Evidence from japan. *American Economic Journal: Macroeconomics*, 10(3):247–77, 2018.

A. Mountford and H. Uhlig. What are the effects of fiscal policy shocks? *Journal of Applied Econometrics*, 24(6):960–992, sep 2009. doi: 10.1002/jae.1079.

A. Orphanides. Monetary policy rules based on real-time data. *American Economic Review*, 91(4):964–985, 2001.

A. Orphanides. Monetary-policy rules and the great inflation. *American economic review*, 92(2):115–120, 2002.

A. Orphanides. Monetary policy rules, macroeconomic stability, and inflation: A view from the trenches. *Journal of Money, Credit and Banking*, pages 151–175, 2004.

A. Orphanides and J. C. Williams. Robust monetary policy rules with unknown natural rates. *Brookings Papers on Economic Activity*, 2002(2):63–145, 2002.

R. Perotti. Defense government spending is contractionary, civilian government spending is expansionary. Technical report, National Bureau of Economic Research, 2014.

G. E. Primiceri. Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies*, 72(3):821–852, 2005.

V. A. Ramey. Identifying government spending shocks: It's all in the timing. *Quarterly Journal of Economics*, 126(1):1–50, 2011. doi: 10.1093/qje/qjq008.

V. A. Ramey. Macroeconomic shocks and their propagation. In *Handbook of macroeconomics*, volume 2, pages 71–162. Elsevier, 2016.

V. A. Ramey and M. D. Shapiro. Costly capital reallocation and the effects of government spending. *Carnegie-Rochester Conference Series on Public Policy*, 48:145–194, 1998. doi: 10.1016/S0167-2231(98)00020-7.

V. A. Ramey and S. Zubairy. Government spending multipliers in good times and in bad: evidence from US historical data. *Journal of Political Economy*, 126(2):850–901, 2018.

C. Ritter and M. A. Tanner. Facilitating the Gibbs sampler: the Gibbs stopper and the griddy-Gibbs sampler. *Journal of the American Statistical Association*, 87(419):861–868, 1992.

C. D. Romer and D. H. Romer. Choosing the federal reserve chair: lessons from history. *Journal of Economic Perspectives*, 18(1):129–162, 2004.

C. D. Romer and D. H. Romer. The most dangerous idea in federal reserve history: Monetary policy doesn't matter. *American Economic Review*, 103(3):55–60, 2013.

J. F. Rubio-Ramirez, D. F. Waggoner, and T. Zha. Structural vector autoregressions: Theory of identification and algorithms for inference. *The Review of Economic Studies*, 77(2):665–696, 2010.

C. Sims. Discussion of cogley and sargent,'evolving post-world war ii inflation dynamics'. *NBER Macroeconomics Annual*, 16, 2001.

J. B. Taylor. Discretion versus policy rules in practice. In *Carnegie-Rochester conference series on public policy*, volume 39, pages 195–214. Elsevier, 1993.

J. B. Taylor. A historical analysis of monetary policy rules. In *Monetary policy rules*, pages 319–348. University of Chicago Press, 1999.

J. B. Taylor. Housing and monetary policy. Technical report, National Bureau of Economic Research, 2007.

H. Uhlig. What are the effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics*, 52(2):381–419, 2005. doi: 10.1016/j.jmoneco.2004.05.007.

C. Walsh. Speed limit policies: the output gap and optimal monetary policy. *American Economic Review*, 93(1):265–278, 2003.

J. Wieland. State-dependence of the zero lower bound government spending multiplier. *Unpublished manuscript*, 2018.

M. H. Wolters. Estimating monetary policy reaction functions using quantile regressions. *Journal of Macroeconomics*, 34(2):342–361, 2012.

M. Woodford. Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics*, 3(1):1–35, 2011.

J. C. Wu and F. D. Xia. Measuring the macroeconomic impact of monetary policy at the zero lower bound. *Journal of Money, Credit and Banking*, 48(2-3):253–291, 2016.

S. Zubairy. On fiscal multipliers: Estimates from a medium scale dsge model. *International Economic Review*, 55(1):169–195, 2014.

A Mathematical Appendix

This section provides a more detailed overview about the new TVP-ST-VAR model used in the main text. The model is a hybrid between the smooth-transition VAR model, popularized by **?**, and a univariate regression with time-varying parameters and stochastic volatility. The latter part is used to estimate the state determining variable z_t which is then employed to distinguish between different monetary policy regimes in the main model. As argued in the main text, this extension is necessary because monetary policy is not well explained by a single observable variable so that the standard approach in the ST-VAR literature is not the optimal choice. In the following, we explain the model in greater details and lay out each step of the estimation procedure. First, the model is characterized via the following equations

$$X_t = (1 - G(z_{t-1}))\Pi_{AM}X_{t-1} + G(z_{t-1})\Pi_{PM}X_{t-1} + u_t \tag{A.1.}$$

$$u_t \sim N(0, \Omega_t) \tag{A.2.}$$

$$\Omega_t = (1 - G(z_{t-1}))\Omega_{AM} + G(z_{t-1})\Omega_{PM} \tag{A.3.}$$

$$G(z_t) = \frac{1}{1 + exp(\gamma(z_t - c))} \tag{A.4.}$$

X_t is a vector of endogenous variables and represents the underlying economy. The state of the economy evolves continuously over time. The model **??** - **??** approximates the true evolution of this state via an evolving mix of two extreme states. Here, monetary policy is purely active in the AM and purely passive in the PM regime. The relative weights assigned to the purely passive regime is given by the transition function G. G is continuous, monotonically decreasing and bounded between 0 and 1. If z_t increases, the value of G decreases and the model assigns relatively more weight towards the AM regime. Here, γ governs the speed with which this transition occurs. If $\gamma \approx 0$, $G \approx 0.5 \forall t$, the model becomes a linear model and no transition occurs. If $\gamma \approx \infty$, the model jumps from one extreme regime to another as soon as z_t the threshold parameter c. In this case, the model becomes a threshold VAR model, thus nesting the Markov-type models.[18]

To characterize monetary policy as the evolving, potential nonlinear, state of the economy, we follow the DSGE literature and estimate an interest-rate rule, i.e., a version of the Taylor rule as introduced by **?**. Because there is strong evidence that the coefficients of the Taylor rule and the variance of the corresponding residuals vary over time, we estimate a Taylor rule with time-varying parameters and stochastic volatility. More formally, we estimate

[18] We exploit this feature in our replication exercise. See Section **??**.

$$y_t = \mathbf{z}_t' \phi_t + e_t,\ e_t \sim N(0, \sigma_t^2) \tag{A.5.}$$

$$\phi_t = \phi_{t-1} + v_t,\ v_t \sim N(0, q) \tag{A.6.}$$

$$log(\sigma_t) = log(\sigma_{t-1}) + \eta_t,\ \eta_t \sim N(0, w) \tag{A.7.}$$

where y_t is the federal funds rate, $\mathbf{z}_t$ consists of a constant, inflation and output. ϕ_t is a vector of time-varying coefficients. ϕ_t follows a random walk process which allows for both temporary and permanent shifts in the parameters. We use the time-varying inflation parameter, $\phi_{\pi,t}$ as z_t in the model **??** - **??**. The variance of the residuals can also vary over time. We assume that $log(\sigma_t)$ follows a random walk.

We estimate **??**-**??** and **??**-**??** separately in two steps using Bayesian estimation techniques. Bayesian methods allow the data to become informative about the model structure. This feature is particularly important because the data are also informative about the evolution of monetary policy which is key to understanding the effect of government spending depends on monetary policy. We next lay out each step of the estimation procedure.

A.1 Estimation of Taylor rule with time-varying coefficients and stochastic volatility

?? and **??** form a linear-Gaussian state space model. This structure allows us to sample the latent states ϕ_t via standard (Kalman) filtering techniques. In contrast, **??** and **??** form a Gaussian but nonlinear state space model. We follow **?** and **?** and transform this structure into a linear-Gaussian state space model and then use standard (Kalman) filtering techniques to sample σ_t. To sample the time-varying coefficients ϕ^T, the stochastic volatility σ^T and the hyperparameter q and w, we employ the following algorithm

Algorithm 1 Multi-Move Gibbs Sampler for TVP Taylor rule

1. Initialize: ϕ_0, q_0, σ_0 and w_0;
2. Draw $\phi^T|X^T, q, \sigma^T, w$ using standard (Kalman) filtering methods;
3. Draw $q|\phi^T$;
4. Draw $\sigma^T|X^T, \phi^T, q, w$ using standard (Kalman) filtering methods;
5. Draw $w|\sigma^T$
6. Repeat steps 2 through 5 and keep the desired number of draws after a burn-in phase.

A.1.1 Time-varying coefficients

Conditional on σ^T and q, **??** is linear and Gaussian with a known variance. Following **?** and **?**, the density of α^T, $p(\alpha^T|X^T, \sigma^T, q)$, can be factored as

$$p(\phi^T|X^T, \sigma^T, q) = p(\phi_T|X_T, \sigma_T, q) \prod_{t=1}^{T-1} p(\phi_t|\phi_{t+1}, X^t, \sigma^T, q) \tag{A.8.}$$

where

$$p(\phi_t|\phi_{t+1}, X^t, \sigma^T, q) \sim N(\phi_{t|t+1}, P_{t|t+1}) \tag{A.9.}$$

$$\phi_{t|t+1} = E(\phi_t|\phi_{t+1}, X^t, \sigma^T, q) \tag{A.10.}$$

$$P_{t|t+1} = Var(\phi_t|\phi_{t+1}, X^t, \sigma^T, q). \tag{A.11.}$$

We use the (forward) Kalman filter to estimate $\phi_{T|T}$ and $P_{T|T}$, the mean and variance of the distribution of ϕ_T. A draw of this distribution is then used in the (backwards) Kalman smoother to estimate $\phi_{t|t+1}$ and $P_{t|t+1}$. Draws from the corresponding distributions yield the whole sequence of ϕ_t for $t = \{1, ..., T-1\}$. A general overview about Kalman filtering techniques is given in Appendix **??**.

A.1.2 Stochastic Volatility

Consider the following model

$$y_t - \mathbf{z}_t' \phi_t = y_t^\star = \sigma_t \xi_t,\ \xi_t \sim N(0, 1) \tag{A.12.}$$

$$log(\sigma_t) = log(\sigma_{t-1}) + \eta_t,\ \eta_t \sim N(0, w) \tag{A.13.}$$

The model **??** and **??** forms a Gaussian, but nonlinear state space model. However, the model can be transformed into a linear model by squaring and taking the log of **??**

$$log(y_t^{\star 2}) = 2log(\sigma_t) + log(\xi_t^2) \tag{A.14.}$$

or

$$y_t^{\star\star} = 2h_t + \nu_t. \tag{A.15.}$$

(**??**) and (**??**) form a linear model, but $\nu_t \sim \ log\,\chi^2(1)$. Following **?** and **?**, we approximate the $log\,\chi^2(1)$ distribution by a mixture of seven normal distributions with weights q_i, means $m_i - 1.2704$ and variance v_i^2. The constants $\{q_i, m_i, v_i^2\}$ are known and provided in Table **??** Following **?** and **?**, we define $s^T = [s_1, ..., s_T]$ where s_t represents the indicator variable, i, that belongs to the normal distribution that is used to approximate the distribution of ν in period t, i.e., $\nu_t|s_t \sim \ N(m_i - 1.2704, v_i^2)$ and $Prob(s_t = i) = q_i$. Then, conditional on ϕ^T, w, s^T and the data (**??**) and (**??**) is approximately linear and Gaussian. This structure implies that h_t can be sampled using standard (Kalman) filtering. Similar to the step that samples ϕ^T, the distribution of h^T can be factored as

$$p(h^T|X^T, \phi^T, w, s^T) = p(h_T|X_T, \phi_T, w, s^T) \prod_{t=1}^{T-1} p(h_t|h_{t+1}, X^t, \phi^T, w, s^T) \tag{A.16.}$$

with

$$p(h_t|h_{t+1}, X^t, \phi^T, w, s^T) \sim \ N(h_{t|t+1}, B_{t|t+1}) \tag{A.17.}$$

$$h_{t|t+1} = E(h_t|h_{t+1}, X^t, \phi^T, w, s^T) \tag{A.18.}$$

$$B_{t|t+1} = Var(h_t|h_{t+1}, X^t, \phi^T, w, s^T). \tag{A.19.}$$

A.1.3 Hyperparameters for q and w

Finally, we discuss the hyperparameters for the variances q and w. Conditional on ϕ^T, σ^T and X^T, the residuals v_t and η_t are observable, and q and w both have an inverse Gamma distribution, i.e.

$$q \sim \ IG(\Psi_T, \psi_T) \tag{A.20.}$$

$$w \sim \ IG(K_T, \kappa_T) \tag{A.21.}$$

where $\Psi_T = \Psi_0 + \sum_{j=1}^{T-1}(\phi_j - \phi_{j-1})'(\phi_j - \phi_{j-1})$, $\psi_0 = \psi_T + T$, $K_T = K_0 + \sum_{j=1}^{T-1}(h_j - h_{j-1})^2$ and $\kappa_T = \kappa_0 + T$ with $\Psi_0 = 0.04 \times \ I$, $\psi_0 = 40$, $K_0 = 1$ and $\kappa_0 = 2$.

Table A.1.: Mixture of Normal Distribution

w	q_i	m_i	v_i^2
1	0.00730	-10.12999	5.79596
2	0.10556	-3.97281	2.61369
3	0.00002	-8.566686	5.17950
4	0.044395	2.77786	0.16735
5	0.34001	0.61942	0.64009
6	0.24566	1.79518	0.34023
7	0.25750	-1.08819	1.26261

Note: See **?** for details.

Figure **??** shows the evolution of the inflation parameter and stochastic volatility. We then use the median estimate of the inflation parameter as z_t in the VAR part of the model.

A.1.4 Kalman filter and smoother

In Sections **??** and **??**, we used standard Kalman filtering methods to filter α^T and σ^T. This section provides a more detailed overview about these methods. Consider the following general state-space model

$$y_t = Z\alpha_t + e_t,\ e_t \sim\ N(0, H) \tag{A.22.}$$

$$\alpha_t = T\alpha_{t-1} + R\eta_t, \eta_t \sim\ N(0, Q). \tag{A.23.}$$

Kalman filtering techniques take Z, H, T, R, Q as given and provide an estimate of α_t via the following forecasting and updating steps

$$a_{t|t-1} = Ta_{t-1} \tag{A.24.}$$

$$P_{t|t-1} = TP_{t-1}T' + RQR \tag{A.25.}$$

$$a_t = a_{t|t-1} + P_{t|t-1}Z'F_t^{-1}(y_t - Za_{t|t-1}) \tag{A.26.}$$

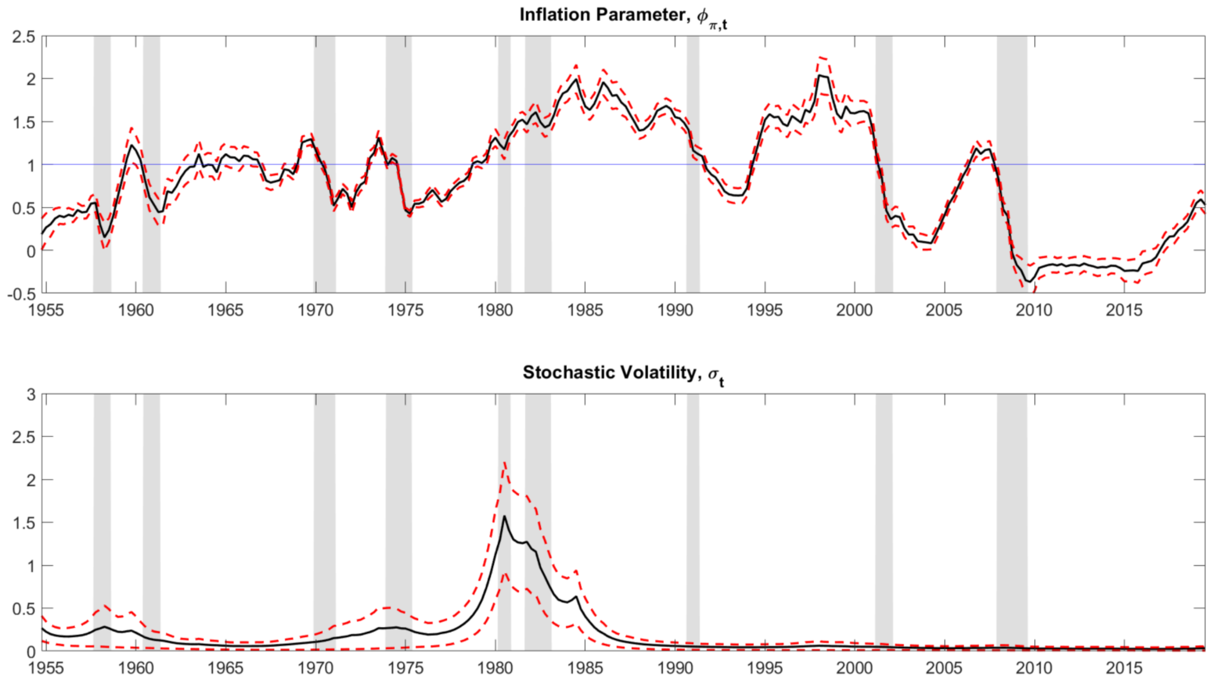
$$P_t = P_{t|t-1} - P_{t|t-1}Z'F_t^{-1}ZP_{t|t-1} \tag{A.27.}$$

where $F_t = ZP_{t|t-1}Z' + H$. The Kalman filter runs forward for $t = 1, ..., T$. Then,

$$\alpha_T \sim N(a_T, P_T). \tag{A.28.}$$

Conditional on α_T, the Kalman smoother runs backwards and samples α_t for $t = T-1, T-$

Figure A.1.: Inflation parameter and Stochastic Volatility



Note: Figure shows the estimated sample paths of $\phi_{\pi,t}$ and σ_t. The black lines represent the median estimates and the red dotted lines correspond to the 68 percent credible bands. Both vary substantially during our sample period.

2, ..., 0 using the following steps

$$\alpha_{t|t+1} = \alpha_t + P_t T P_{t+1|t}^{-1}(\alpha_{t+1} - Z a_t) \tag{A.29.}$$

$$P_{t|t+1} = P_t - P_t T P_{t+1|t}^{-1} T P_t \tag{A.30.}$$

Then, $\alpha_t \sim N(\alpha_{t|t+1}, P_{t|t+1})$ for $t = T-1, T-2, ..., 0$.

A.2 Estimation of the ST-VAR model

In this section, we describe the Bayesian estimation of the ST-VAR model. To sample the model parameters $\{\pi_{AM}, \pi_{PM}, \Omega_{AM}, \Omega_{PM}, c, \gamma\}$, we employ the following algorithm:

Algorithm 2 Multi-Move Gibbs Sampler for ST-VAR model

1. Initialize: Choose $\pi^0_{AM}, \pi^0_{PM}, \Omega^0_{AM}, \Omega^0_{PM}, \gamma^0, c^o$;
2. Draw $\pi_{AM}|\Omega_{AM}, \Omega_{PM}, \gamma, c \sim N(m_{AM}, V_{AM})$ and $\pi_{PM}|\Omega_{AM}, \Omega_{PM}, \gamma, c \sim N(m_{PM}, V_{PM})$;
3. Draw $\gamma|\pi_{AM}, \pi_{PM}, \Omega_{AM}, \Omega_{PM}, c$ using a Metropolis-Hastings step;
4. Draw $c|\pi_{AM}, \pi_{PM}, \Omega_{AM}, \Omega_{PM}, \gamma$ from a Griddy Gibbs sampler;
5. Draw $\Omega_{AM}, \Omega_{PM}|\pi_{AM}, \pi_{PM}, \gamma, c$ using a Metropolis-Hastings step;
6. Repeat steps 2 through 5 and keep the desired number of draws after a burn-in phase.

A.2.1 Sample Π_E and Π_R

Define $\pi_r = vec(\Pi_r)$ for $r \in \{AM, PM\}$. For π_{AM} and π_{PM}, we choose the Minnesota prior, i.e.,

$$p(\pi_r) \sim N(m_0, V_0). \tag{A.31.}$$

The Minnesota prior assumes that X_t follows a multivariate random walk process. π_0 is a vector equal to zero, except for the elements that correspond to a variable's own lags. In this way the Minnesota prior shrinks many parameters of π_r towards zero. In addition, V_0 has the following form

$$V(i,j)_0 = \begin{cases} \frac{\theta_1}{\ell^2} & \text{for parameter on own lags, } j = i \\ \frac{\theta_2 \sigma^2_{s,i}}{\ell^2 \sigma^2_{s,j}} & \text{for parameter on foreign lags, } j \neq i \end{cases} \tag{A.32.}$$

where ℓ is the lag length and θ_1 and θ_2 are two hyperparameters. The Minnesota prior is a conjugate prior, which implies that the posterior distribution has the same form as the likelihood as the data. Therefore, the posterior of π_r is also normal, i.e.,

$$p(\pi_r|X^T, \Omega_r, \gamma, c) \sim N(m_r, V_r) \tag{A.33.}$$

where

$$V_r = \left((X'_{r,t-1}X_{r,t-1} \otimes \Omega_r^{-1}) + V_0^{-1}\right)^{-1} \tag{A.34.}$$

$$m_r = V_r \times \left((X'_{r,t-1}X_{r,t-1} \otimes \Omega_r^{-1})\hat{\pi}_r + V_0^{-1}\pi_0\right) \tag{A.35.}$$

A.2.2 Sample γ

The posterior distribution of γ does not have a closed-form expression. Hence, we also rely on MCMC methods to approximate the marginal posterior distribution of γ. We follow **?** and **?** and use the Metropolis-Hasting algorithm to draw γ. Denote $\gamma^\star$ as a candidate draw from the proposal density $q(\gamma^\star|\gamma^{k-1})$ where γ^{k-1} is the draw from the previous iteration. Then, we set $\gamma^k = \gamma^\star$ with probability

$$\alpha(\gamma^\star|\gamma^{k-1}) = min\{\frac{p(\gamma^\star|\cdot)/q(\gamma^\star|\gamma^{k-1})}{p(\gamma^{k-1}|\cdot)/q(\gamma^{k-1}|\gamma^\star)}, 1\} \tag{A.36.}$$

$p(\gamma^\star|\cdot)$ is the posterior distribution of $\gamma^\star$ while $p(\gamma^{k-1}|\cdot)$ is the posterior distribution of γ^{k-1}. Moreover, $q(\gamma^\star|\gamma^{k-1})$ and $q(\gamma^{k-1}|\gamma^\star)$ are the corresponding proposal densities. Under mild regularity conditions, the sequence of γ^k, after a sufficient burn-in phase, will approximate the true marginal posterior distribution of γ.

A.2.3 Sample c

The threshold parameter c does not have a closed-form for its posterior distribution. Again, we follow **?** and use the Griddy-Gibbs sampler proposed by **?** to draw c, where c is bounded between the minimum and maximum value of z_t. First, we select grid points to evaluate the density of z_t at these grid points and compute the corresponding (inverse) CDF. Second, we draw a random variable from a standard uniform distribution and plug it into the inverse CDF of z_t. This yields a draw from the marginal posterior distribution of c.[19]

A.2.4 Sample Ω_E and Ω_R

We assume that the purely AM and PM regimes are characterized not only by their own coefficient matrix Π_{AM} and Π_{PM}, but also by their own covariance matrix Ω_{AM} and Ω_{PM}. Under the assumption of heteroskedasticity, Ω_{AM} and Ω_{PM} are not conjugate. In addition, the joint posterior distribution of Ω_{AM} and Ω_{PM} cannot be written as the product of their marginal posterior distributions. Hence, they are also not independent and must be drawn jointly. We follow **?** and use the Metropolis-Hastings algorithm proposed by **?** to sample Ω_{AM} and Ω_{PM}. Denote $\Omega^\star_{AM}$ and $\Omega^\star_{PM}$ as a pair of candidate draws from the proposal densities $q(\Omega^\star_{AM}|\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM})$ and $q(\Omega^\star_{PM}|\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM})$, respectively. Ω^{k-1}_{AM} and Ω^{k-1}_{PM} are draws from the previous iteration. Then, we set $\{\Omega^k_{AM}, \Omega^k_{PM}\} = \{\Omega^\star_{AM}, \Omega^\star_{PM}\}$ with probability

$$\alpha(\Omega^\star_{AM}, \Omega^\star_{PM}|\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM}) = min\{\frac{p(\Omega^*_E, \Omega^*_R|\cdot)/q(\Omega^*_E, \Omega^*_R|\cdot)}{p(\Omega^{k-1}_E, \Omega^{k-1}_R|\cdot)/q(\Omega^{k-1}_E, \Omega^{k-1}_R|\cdot)}, 1\} \tag{A.37.}$$

[19] This property is known as the inversion method. Suppose X is random variable with an unknown distribution and u is standard uniformly distributed. Then $F^{-1}(u)$ can be used to generated draws of X with the specified CDF F.

$p(\Omega^*_{AM}, \Omega^*_{PM}|\cdot)$ and $p(\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM}|\cdot)$ are the corresponding posterior distributions of $\Omega^\star_{AM}, \Omega^\star_{PM}$ and $\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM}$. Moreover, $q(\Omega^*_{AM}, \Omega^*_{PM}|\cdot)$ and $q(\Omega^{k-1}_{AM}, \Omega^{k-1}_{PM}|\cdot)$ are their respective proposal densities. Under relative mild regularity conditions, the sequences of $\{\Omega^k_{AM}, \Omega^k_{PM}\}$, after a sufficient burn-in phase, will approximate the true posterior distribution of Ω_{AM} and Ω_{PM}.

A.3 Generalized Impulse Response Functions

In nonlinear models, the impulse response parameters depend on the shock sign, the shock size and the timing of the shock. Furthermore, the state of the economy can change over time and after the shock. To incorporate these features, we follow **?** and use generalized impulse response functions to estimate the dynamic effects of the shock. The generalized impulse responses defined as the difference of two simulated paths of the economies, i.e.,

$$\begin{aligned} GIRF(h) = {} & (1 - G(z_{t+h-1}))\,\Pi_{AM} X_{t+h-1} + G(z_{t+h-1})\Pi_{PM} X_{t+h-1} + u^\epsilon_{t+h} \\ & - (1 - G(z_{t+h-1}))\,\Pi_{AM} X_{t+h-1} + G(z_{t+h-1})\Pi_{PM} X_{t+h-1} + u_{t+h} \end{aligned} \tag{A.38.}$$

First, we draw a set of reduced form parameters $\Omega_{AM}, \Omega_{PM}, \Pi_{AM}$ and Π_{PM}. Second, the generalized impulse response functions require an initial condition. Hence, we draw an initial condition that comes with the lags for the VAR X_{t-1}, the value of the state variable z_{t-1} and a sequence of the reduced-form residuals of H periods u^H_t. Third, we transform the sequence of reduced form residuals into structural shocks and “back”

$$\epsilon_{t+h} = (Chol(\Omega_t)Q)^{-1}\, u_{t+h} \tag{A.39.}$$

$$\tilde{\epsilon}_{t+h} = \epsilon_{t+h} + \delta \tag{A.40.}$$

$$u^\epsilon_{t+h} = Chol(\Omega_t)Q\tilde{\epsilon}_{t+h} \tag{A.41.}$$

where δ represents the shock size, $Chol(\Omega_t)$ is the Cholesky decomposition of Ω_t and Q is an orthogonal matrix, called *rotation* matrix. We follow **?** and draw Q from the Haar measure via the QR decomposition of a matrix of standard normal random variables. Fourth, conditional on the starting period, we roll the model forward using Equation (**??**) of our main model and add the value of u_{t+h} to the path of the economy without the government spending shock and u^ϵ_{t+h} to the path of the economy with the government spending shock. Fifth, we take the difference between the simulated economies to obtain one candidate draw of the generalized impulse response functions. If the candidate satisfies the sign restrictions, we store the draw. If not, we discard the candidate, draw a new rotation matrix and check again if the imposed sign restrictions are satisfied. We repeat this procedure until a sufficient number of candidates are accepted and move to the next initial condition. Then, we average over the accepted candidates and initial conditions to obtain one realization of the generalized impulse response functions. Finally, we repeat the whole procedure for the next draw of the reduced form parameters, $\Omega_{AM}, \Omega_{PM}, \Pi_{AM}$ and Π_{PM}. This procedure yields a distribution of generalized impulse response functions that are consistent with our sign restrictions.

B Taylor Rules

This section discusses some of the issues related to the estimation of Taylor rules. This is an important section because the inflation parameter of the Taylor is used in our main model to distinguish between different monetary policy regimes. The estimation of Taylor rules has spurred a large amount of research that needs to be reviewed in the context of our study.

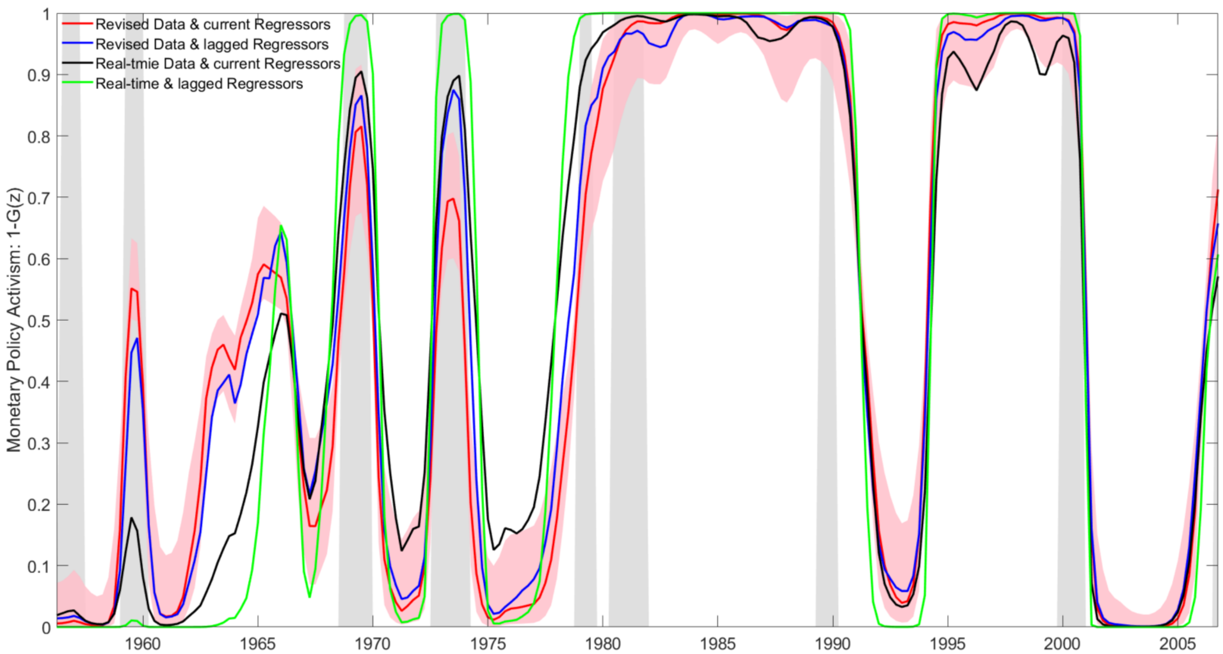
? estimates a simple Taylor rule by regressing the federal funds rate as the monetary policy instrument on real output and the inflation rate using least squares. **?** also estimates a simple Taylor rule. However, they exploit a large set of instruments and employ general methods of moments. Both studies find that monetary policy changed considerably before and after 1980. However, both studies use revised data. **???** and **?** suggest real time data should be used because revised data may contain information that were unavailable to policy makers during the time they faced policy decisions. These studies find that monetary policy may also have been active in the 1970s, which contradicts the conclusion drawn by **?** and **?**.

Moreover, **?** find that monetary policy has varied substantially over time as well. **?** argues that the change in monetary policy is due to time-varying heteroskedasticity in the Taylor-rule residuals. However, **?** demonstrate that their 2001-results are robust when after accounting for stochastic volatility in their model.

? illustrate that the Taylor rule residuals are serially correlated. In this case, instruments such as lagged regressors, real time data or the **?**'s instruments are not necessarily valid instruments. However, the resulting endogeneity problem does not cause a substantial bias. Finally, **?** provide evidence that the bias of a Taylor rule estimated with least squares is small.

To sum up, the estimation of Taylor rules has spurred extensive research. The key question is whether monetary policy has changed over time. According to the literature, the choice of the data (revised vs. real time data) and assumptions regarding the residuals (constant vs. stochastic volatility) might be important. Recent evidence, however, suggests that differences in the estimators are small. In this section, we estimate the Taylor rule in four different specifications: (i) revised data with current inflation and real GDP growth rates (main specification used in the paper), (ii) revised data with lagged inflation and real GDP growth rates, (iii) real-time data with current inflation and real GDP growth rates, and (iv) real-time data data with lagged inflation and real GDP growth rates.[20] Figure **??** presents the corresponding evolutions of $1 - G(z_{t-1})$.

Figure B.1.: G with revised vs. real-time Data

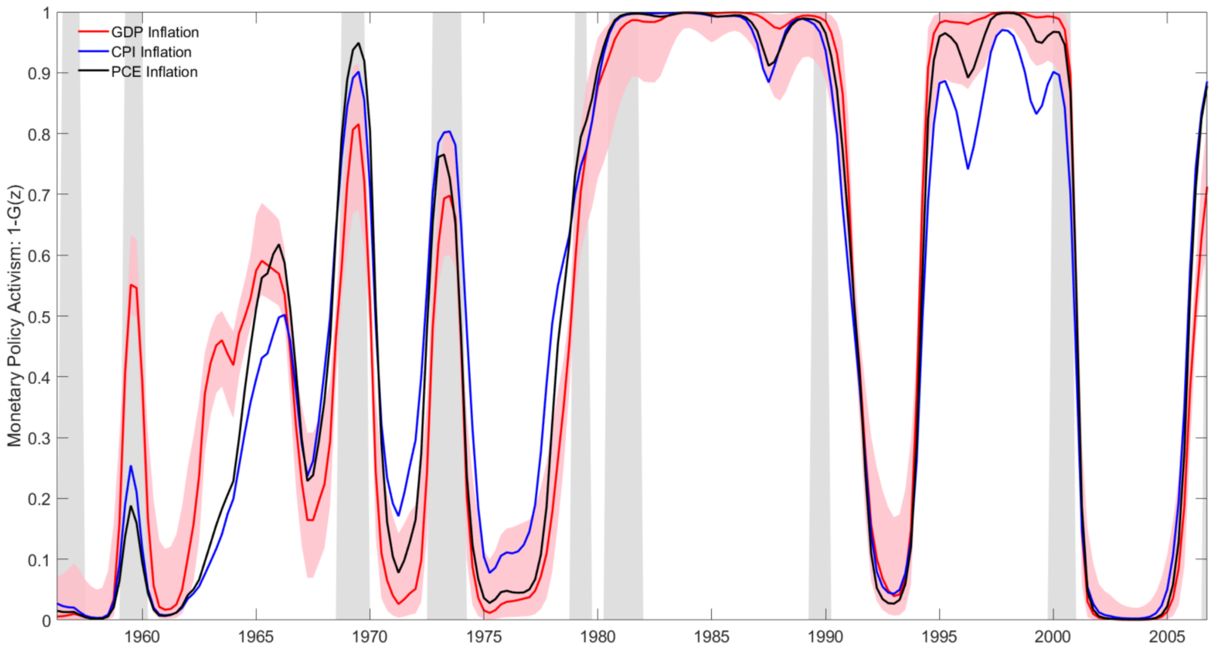


Note: The Figure displays the evolution of $1 - G(z_{t-1})$ using current and lagged regressors and revised and real-time data. The results indicate that if differences exists, they are small and appear in the pre-Volcker period.

Figure **??** presents the evolution of $1 - G(z_{t-1})$ rather than the evolution of the inflation parameter because $1 - G(z_{t-1})$ determines the dynamics of our model in the main text while the inflation parameter is just an ingredient of $G(z_{t-1})$. Figure **??** shows that there exists differences between revised vs real time data and between current and lagged regressors. However, these differences are small and mostly arise in the pre-Volcker era. For example, not all estimations "recognize" the Martin disinflation in 1959/60. However, all estimated evolutions capture the change in monetary policy around 1980, the responses to the 1957/58, 1990/91 and 2000/01 recessions and the substantial deviation from the Taylor principle between 2002 and 2005.

[20] In the next iteration of the paper, we add the Taylor rule estimated using **?**'s approach.

Figure B.2.: Monetary Policy with different Price Indices



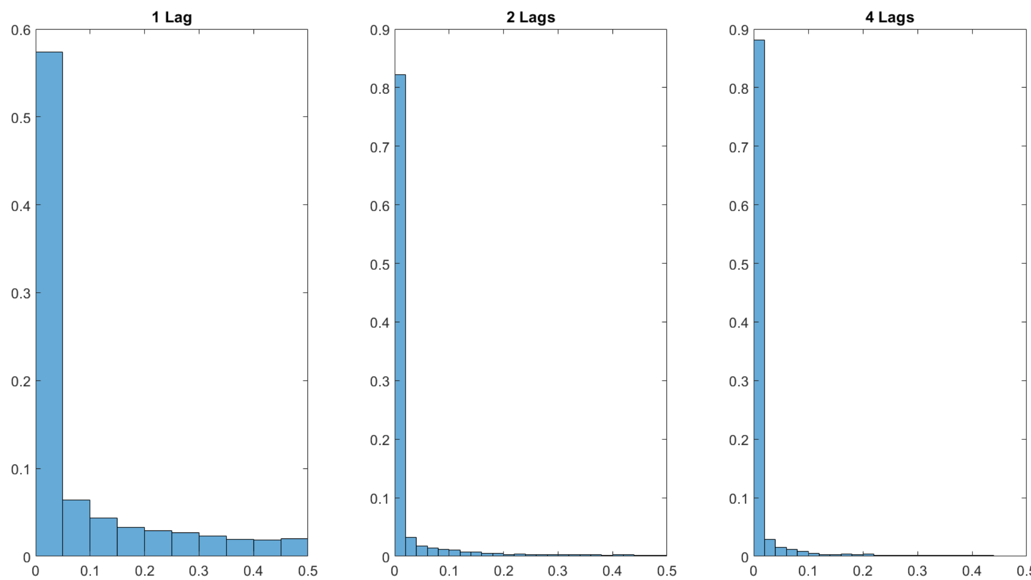
Note: The Figure displays the evolution of $1 - G(z_{t-1})$ using different price indices to compute inflation. The results indicate that if differences exists, they are small and appear in the pre-Volcker period.

Another way to test the robustness of our results is to use different prices indices to compute inflation. In Figure **??**, we show that $1 - G(z_{t-1})$ displays a similar path regardless of whether we compute inflation based on (i) the GDP deflator, (ii) CPI or (iii) PCE. As in Figure **??**, if differences exists, they appear in the pre-Volcker era. For example, the Martin disinflation is not as pronounced for CPI or PCE as it is for the GDP deflator. In contrast, all three specifications display the changes in monetary policy in 1957/58, around 1980, 1990/91, 2000/01 or between 2002-2005.

A possible explanation for the similar estimates of $1 - G(z_{t-1})$, regardless of whether we use (i) current or lagged regressors, (ii) revised or real-time data or (iii) different price indices to compute inflation, is serial correlation in the residuals of the different Taylor rule specifications. To investigate this feature of the residuals, we conduct the Ljung-Box Q-Test.

We use Bayesian methods to estimate the different Taylor rules. Hence, we can also compute the posterior distribution of the residuals. We then conduct the Ljung-Box Q-Test on each draw of the residuals. The null of the Ljung-Box Q-Test is that the residuals are not serially correlated. In Figure ??, we show the distributions of p-values of this test with one, two and five lags for our baseline specification. Figure ?? provides strong evidence for serial correlation in the residuals. For example, the share of p-values that is below 0.05 for the test with one lag is between 0.5 and 0.6. This implies that 50-60 percent of the p-values are below 0.05. For the tests with two and fours lags, the share of small p-values increases to above 80 percent. This test for our baseline specification provides strong evidence that the residuals are indeed serially correlated. According to ?, if the residuals of the Taylor rule are serially correlated, the estimation using standard instruments such as lagged regressors or the ?'s instruments face endogeneity problems, but the resulting bias is small.

Figure B.3.: Ljung-Box Q-Test



Note: Figure shows the distribution of p-values for a Ljung-Box Q-Test. The Ljung-Box Q-Test tests for serial correlation in the residuals of the estimated Taylor rule. We conduct the Ljung-Box Q-Test with one, two and four lags for each draw of the Taylor rule residuals. The Figure shows strong evidence that the residuals of the estimated Taylor rule exhibit serial correlation. For example 57 percent of the p-values for the Test with one lag is below 0.05. For the tests with two and four lags, the percentage is larger.

C Additional Results

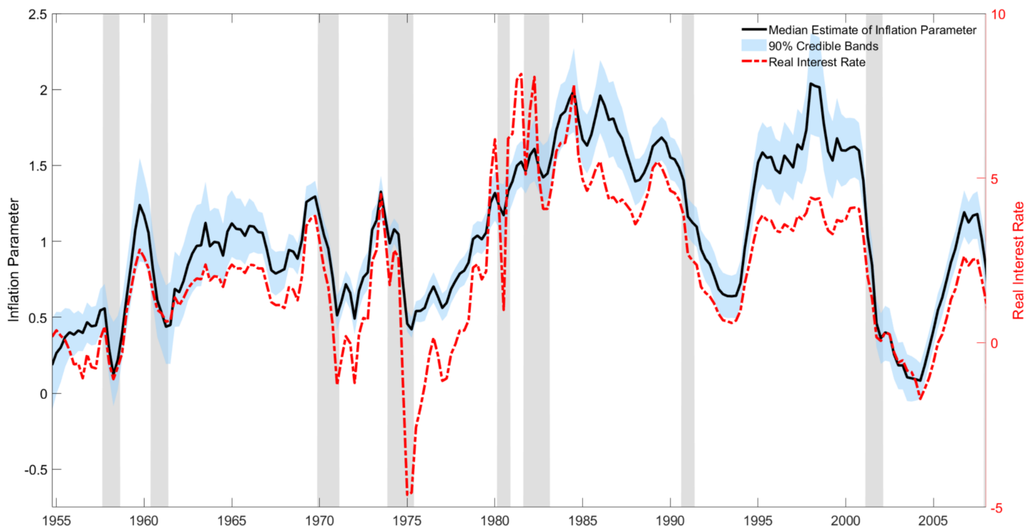
This appendix provides supplemental results. We (i) elaborate on the relationship between the real interest rate and our estimated evolution of monetary policy, (ii) include a different measure for agents' expectations regarding future government spending plans, (iii) compare different identifications strategies, (iv) examine the consequences of the binary interpretation of monetary policy, (v) compare different updating rules for the state variable after the government spending shock, and (vi) consider different shock signs and different shock sizes.

C.1 Monetary Policy and the real interest rate

When we study the evolution of monetary policy, we face the difficulty that we do not have a natural comparison. For example, **?** show that their estimated evolution of the business cycle is well aligned with the NBER recessions. For monetary policy, there does not exists such a natural benchmark. However, when theorist make their predictions about whether the government spending multiplier also depends on monetary policy, they also refer to the real interest rate. Hence, in Figures **??** and **??**, we compare the estimated evolution of the inflation parameter $\phi_{\pi,t}$ and the transition function $1 - G(z_{t-1})$ with the real interest rate defined as the difference between the federal funds rate and annualized inflation based on the GDP deflator.

Figure **??** illustrates that the estimated sample path of $\phi_{\pi,t}$ and the sample path of the real interest rate align well. During times of a responsive central bank (high $\phi_{\pi,t}$), real interest rates are high and vice versa. In addition, changes in $\phi_{\pi,t}$ and changes in the real interest rate occur at almost the same time. For example, in 1959, $\phi_{\pi,t}$ increases from almost zero to above one. The real interest rate change exactly at the same. Moreover, between 1975 and 1980, $\phi_{\pi,t}$ increases from around 0.5 to almost two. At the same time, the real interest rate displays its largest increase or our sample period. A similar relationship is demonstrated in Figure **??**. When monetary policy was very passive e.g., during the late 1950s, second half of 1970s or the first half of the 2000, real interest rates were relatively low. In contrast, when monetary policy was very active e.g., during the 1980s or the second half of the 1990s, real interest rates were relatively high. Finally, when monetary policy changed and becomes more active, real interest rates increase and vice versa if monetary policy becomes more passive.

Figure C.1.: The sample paths of $\phi_{\pi,t}$ and the real interest rate



Note: The red line shows the sample path of the real interest rate and the black line presents the posterior median of the $\phi_{\pi,t}$ along with the 68 percent credible bands in blue. The Figure establishes a close relationship between the two.

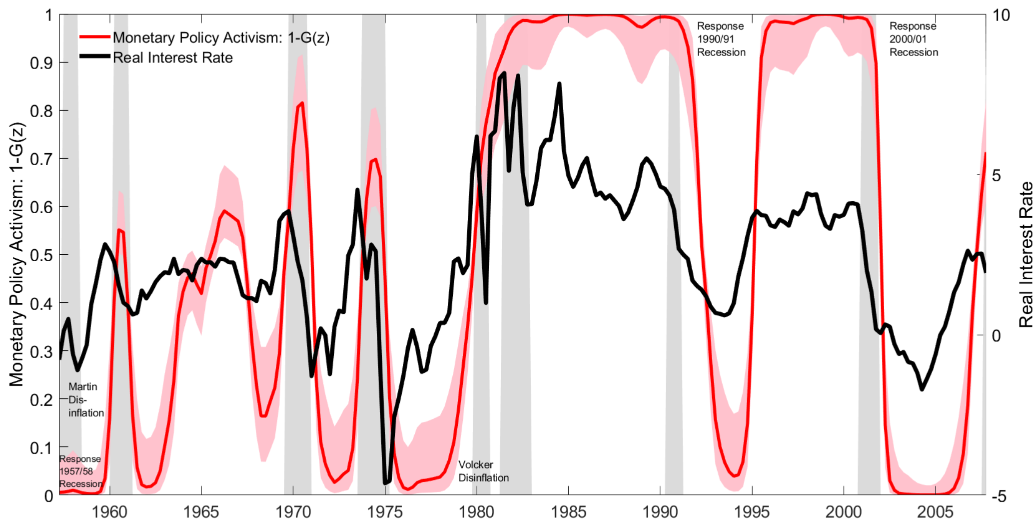
C.2 Alternative measures for agent's expectations regarding future government spending plans

In our baseline specification, we augment our information set with Ramey's news shocks to account for agent's expectations regarding future government spending plans. This approach is one way to account for fiscal foresight. Fiscal foresight is an example of the *non-fundalmentalness* problem that arises because the econometrician cannot observe all relevant information to recover structural shocks. In this case, a VMA model of the economy does not have a VAR representation, so a VAR cannot consistently estimate impulse response functions.[21]

? argues that her news shock series is not very informative for the post-Korean war period. Despite this concern, we include Rameys news shocks in our baseline specification as it has remained the standard expectation variable in the literature. In this section, we conduct a robustness check in which we re-estimate our replication exercise from Section

[21]See (**???**)

Figure C.2.: The sample paths of $1 - G(z_{t-1})$ and the real interest rate



Note: The red line shows the median estimate of $1 - G(z_{t-1})$ along with the 68 percent credible bands in pink. The black line corresponds to the real interest rate. The Figures demonstrates that during times of passive monetary policy, the real interest rate is relatively low and vice versa during times of active monetary policy.

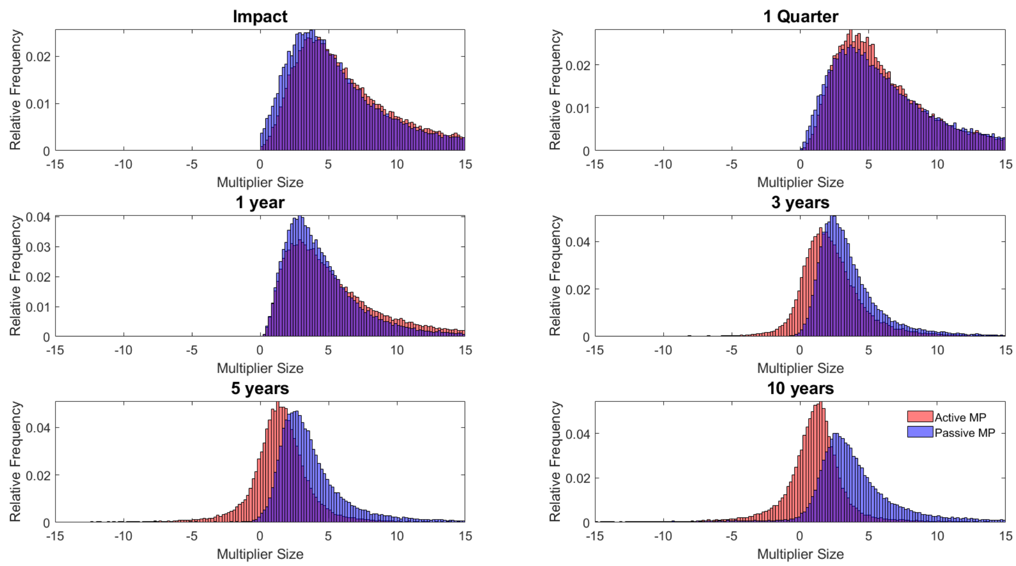
?? but replace Ramey's news shocks with the shock series from **?**. **?** define a government spending shock as the shock that "best explains future movements in defense spending over a five-year horizon and is orthogonal to current defense spending".

Figure **??** shows that the results are very similar to our baseline specification in Figure **??**. The multiplier estimates are comparable across monetary policy regimes up to one year after the shock. One year after the shock, the multiplier starts to diverge and is estimated to be higher in the long-run. These results mirror those in **?**, who find that the multiplier is similar across monetary policy regimes in the short-run but diverges in the long-run.

C.3 Consequences of the binary interpretation of monetary policy

We now demonstrate the consequences of the binary interpretation of monetary policy. We repeat our main exercise but only distinguish between active and passive monetary policy. Using the generalized impulse response functions, we must employ a threshold value: If

Figure C.3.: Multiplier Estimates in Model with large γ and **?** Shocks



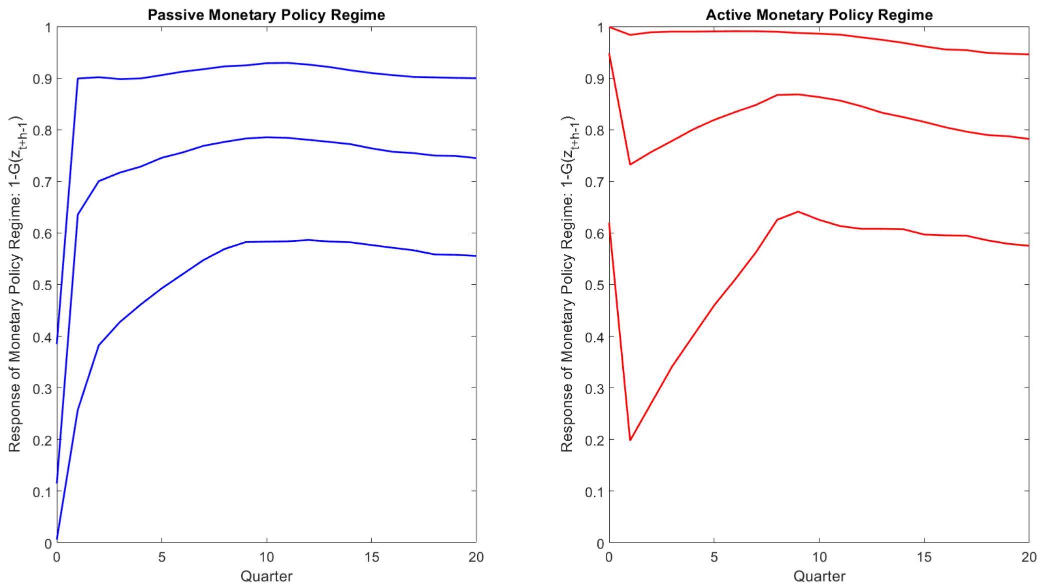
Note: Figure compares the estimated multipliers when monetary policy is and remains purely active (red) and purely passive (blue) after the shock. In this Figure, we replace the Ramey's news shocks by the **?** shocks to account for fiscal foresight. The result show that the multipliers diverge when monetary policy is and remains purely passive. This result is similar those in Figure **??**.

$G(z_{t-1}) \geq 0.5$, then the monetary policy regime in t is declared as "passive" and as "active" otherwise. We then estimate the generalized impulse response function for both regime drawing random initial conditions from the two subsets.

Figure **??** shows the response of the monetary policy regime to the government spending shock. If monetary policy is initially "active", the central bank changes its policy regime only slightly. In contrast, if the initial regime is "passive", the central bank responds quickly and transitions fast to the "active" regime. Shortly after the shock, the central bank responds aggressively to inflation regardless of the initial regime. Figure **??** illustrates that the government spending multiplier does not depend on the initial monetary policy regime – either in the short-run or in the long-run. These results mirror our main findings.

In section **??**, we also find that monetary policy is not just active or passive but differences exists even within these broader regime in terms of how active or passive the monetary policy regime can be. In Figure **??**, we demonstrate the consequences of the binary interpretation

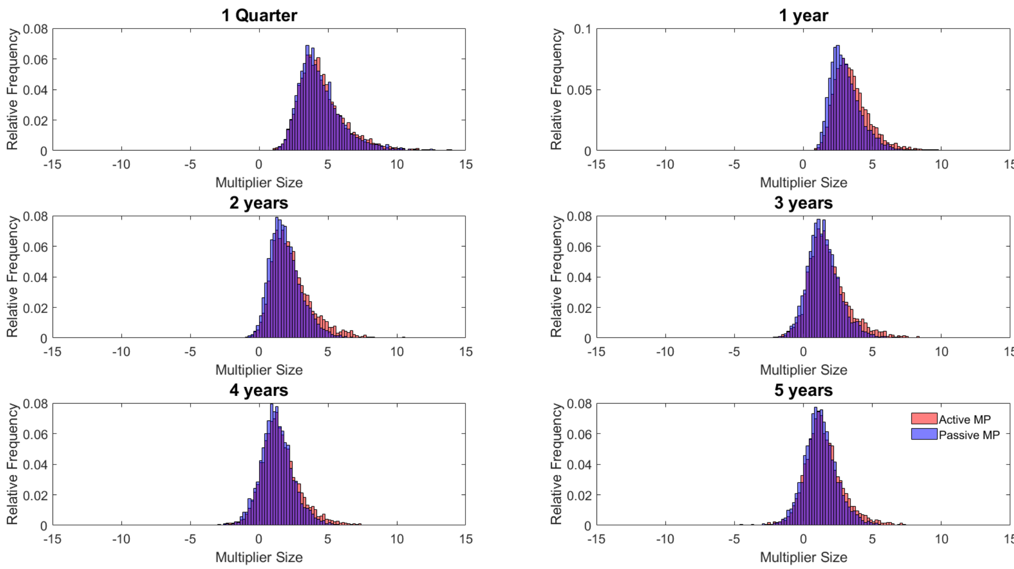
Figure C.4.: Evolution of $G(z_{t-1})$ after a Government Spending Shock



Note: Figure shows that the central banks responds quickly after the shock and transitions to the "active" regime if the initial regime is "passive". As a result, shortly after the shock and regardless of its initial condition, the central bank responds actively to inflation.

of monetary policy when the regime is in fact continuous. Figure **??** plots the distribution of $G(z_{t-1})$ to display the distribution of initial monetary policy regimes. There are two spikes close to zero and one. However, there are also many lieing in the interior of the unit interval, many of them lie close to the threshold value. This casts doubt on the idea that these "active" and "passive" GIRFs are representative of the ends of the spectrum. Rather, on average, we compare initial monetary policy regimes of $0{:}14$ and $0{:}84$ to each other. These values are far from the monetary policy regimes of zero and one, but also incorporate many observations in the neighborhood of .5. The binary approach to GIRFs could fail to identify interesting variation. For example, **?** and **?** compare spending multipliers between expansions and recessions relying on the binary interpretation of the business cycle. Both studies conclude that there are no significant differences in the estimated multipliers. However, results thus obtained are difficult to interpret because they could come from two sources: (i) multipliers that are indeed regime-independent; or (ii) underlying regimes that

Figure C.5.: Multiplier Estimates when monetary policy is responsive but binary



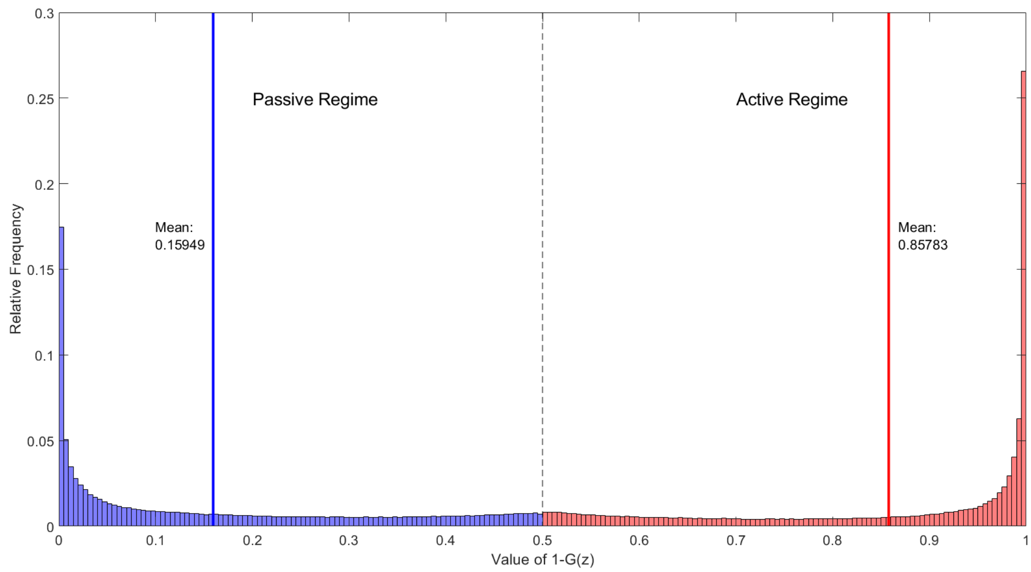
Note: The Figure displays the multiplier estimates for the scenario when the monetary policy regime is responsive but binary. Regardless of the identification strategy and forecast horizon, there does not seem to exist any evidence that the government spending multiplier depends on monetary policy. However, the binary interpretation of monetary policy misplaced and causes findings to be misleading.

are not sufficiently different.

C.4 Alternative Updating Rules for z_t

In the main text, we use the Kalman filter based on the forecasted values of the federal funds rate, inflation and output growth to forecast the inflation parameter as the state variable. Using the new value of the state variable, we update the weights $G(z_{t+h})$ and $1-G(z_{t+h})$ on the purely passive and purely active monetary policy regimes. In this way, the government spending shock affects monetary policy, and changing monetary policy further impacts the transition of the government spending shock. However, other rules to update the inflation parameter of the Taylor rule are also conceivable. For example, we can run a regression based on forecasted values of inflation on the forecasted values of inflation and output growth, i.e.

Figure C.6.: Distribution of initial Monetary Policy regimes



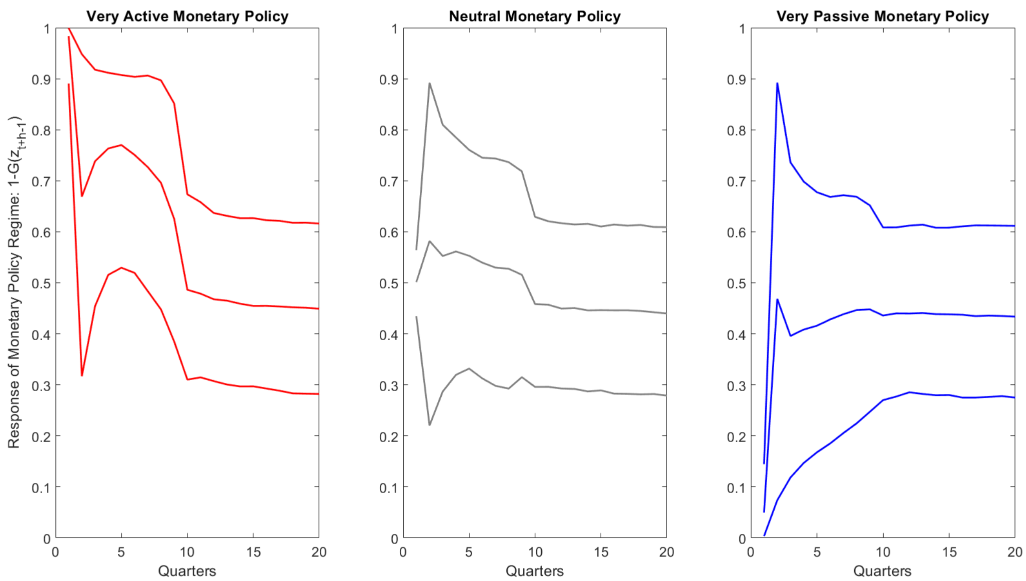
Note: Bisecting the sample into "active" and "passive" regimes based on the initial value of G lumps many of the central observations into one regime or the other. However, many initial monetary policy regime are close to the threshold value of 0.5 and the "distinct" regimes are relatively close to each other.

$$\hat{i}_{t+h} = \hat{c}_{t+h} + \hat{\phi}_{\pi,t+h}\hat{\pi}_{t+h} + \hat{\phi}_{y,t+h}\hat{y}_{t+h} + \hat{\epsilon}_{mp,t}. \tag{C.1.}$$

Then, we can use the point estimate of $\hat{\phi}_{\pi,t+h}$ as z_{t+h} to update the weights $G(z_{t+h})$ and $1 - G(z_{t+h})$. Alternatively, we can forecast the inflation parameter $\phi_{\pi,t+h}$ using a AR(1) process with an exogenously given persistence parameter ρ, i.e.,

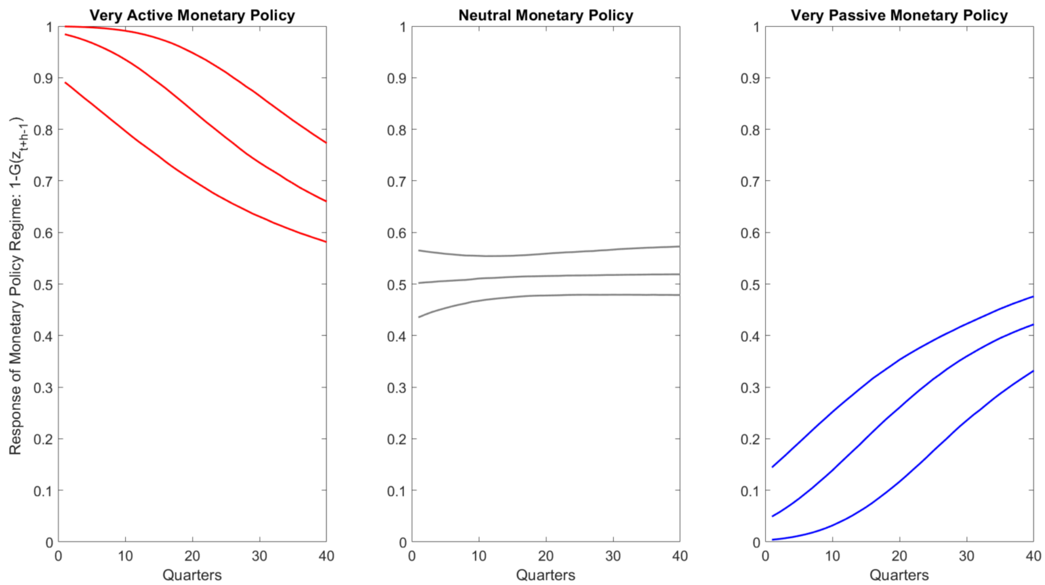
$$\phi_{\pi,t+h} = \rho\phi_{\pi,t+h-1}. \tag{C.2.}$$

Figure C.7.: Response of the Monetary Policy Regime using an updating regression



Note: Figure shows the evolution of $1 - G$ after a government spending shock when monetary policy is initially "very active", "neutral" and "very passive" regime. Regardless of the initial regime, monetary policy converges quickly to the "neutral" policy regime.

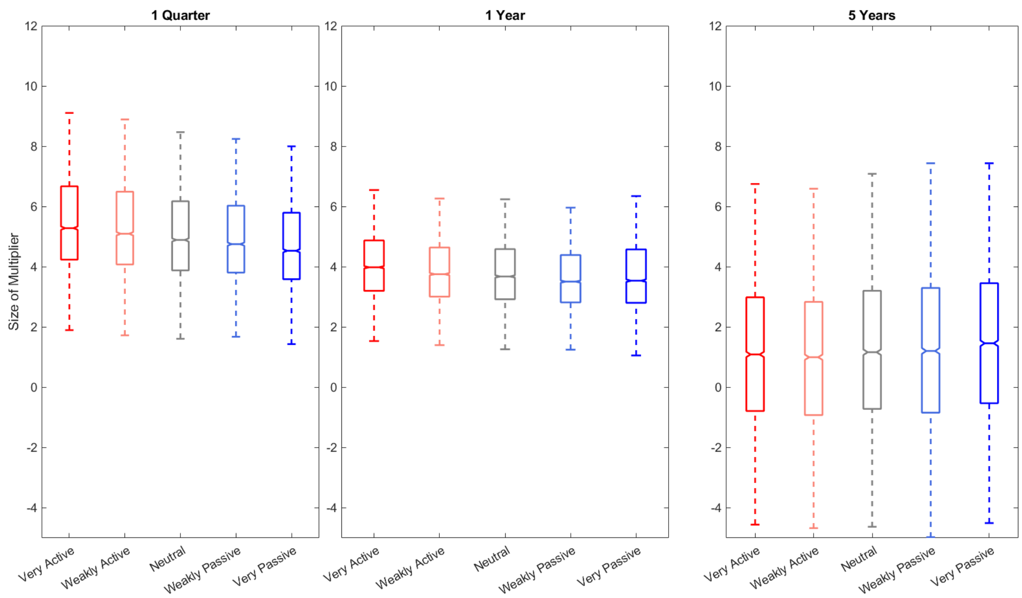
Figure C.8.: Response of the Monetary Policy Regime using an updating AR(1) process with an exogenous persistence parameter



Note: Figure shows the evolution of $1-G$ after a government spending shock when monetary policy is initially "very active", "neutral" and "very passive" regime using an updating AR(1) process with an exogenous persistence parameter that is set to 0.95. Convergence in the policy regime is slow.

Figures **??** and **??** compare the response of the monetary policy regime to the government spending shock. If we use the updating regression to forecast $\phi_{\pi,t+h}$ after the government spending shock, then regardless of its initial regime, the monetary policy regimes react quickly and converge towards the sample mean (0.49). Ten quarters after the shock, the monetary policy regime is the same. In contrast, if we use an AR(1) process and set the persistence parameter equal to 0.95, the monetary policy regime also responds after the shock, but only if it is initially "very active" or "very passive". In addition, the response is much slower than that using the updating regression. 10 years after the shock, the monetary policy regime still has not fully converged.

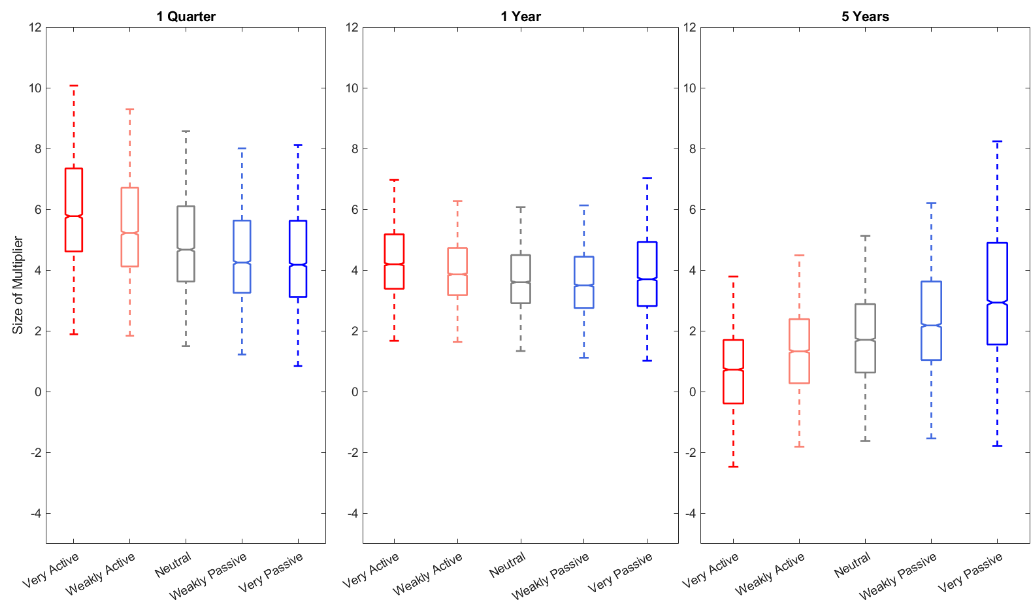
Figure C.9.: Estimated Multipliers across Monetary Policy regimes using an updating regression



Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots and an updating regression. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. Estimated multipliers decrease with time but do not depend on the initial policy regime.

Finally, we compare multiplier estimates across the initial monetary policy regime using boxplots using the updating regression and the AR(1) process in Figures **??** and **??**. In Figure **??**, the government spending multiplier does not depend on the monetary policy regime, either in the short- or long-run. This result is in line with our main conclusion that the government spending multiplier does not depend on the monetary policy regime once we account for the subsequent endogenous response of the policy regime. In contrast, if we apply the exogenous AR(1) process to update the inflation parameter, the government spending multiplier differs across monetary policy regime is estimated to be higher if monetary policy is initially "very passive". This finding is in line with the result of our counterfactual exercise that says that if the monetary policy regime is different for a sufficiently long period of time, then the government spending multiplier depends on monetary policy as suggested by the conventional wisdom. However, because the central bank responds fast after the government spending shock and transition fast to a similar regime, we can infer that it is the constant-regime assumption that drives this consensus.

Figure C.10.: Estimated Multipliers across Monetary Policy regimes using an updating AR(1) process

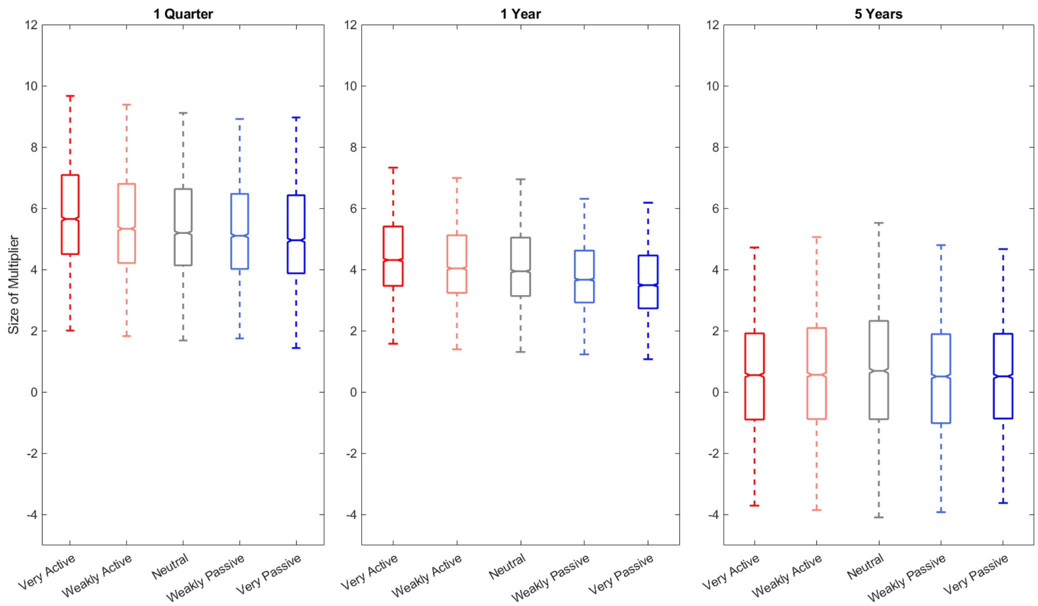


Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots and an updating regression. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. Estimated multipliers decrease with time and depend on the monetary policy regime.

C.5 Different Shock Sizes and different Shock Signs

In this last section, we exploit a specific characteristic of nonlinear time series models such as ours. In nonlinear time series models, impulse response functions may depend on the shock sign or the shock size. Therefore, we now look at whether the government spending multipliers depends on monetary policy regimes if we vary the shock size and shock sign. First, Figures **??** and **??** compare the multiplier estimates across monetary policy regime when the government spending shock is large (two standard deviations) and small (half a standard deviation), respectively.

Figure C.11.: Estimated Multipliers across Monetary Policy regimes for large Government Spending Shock

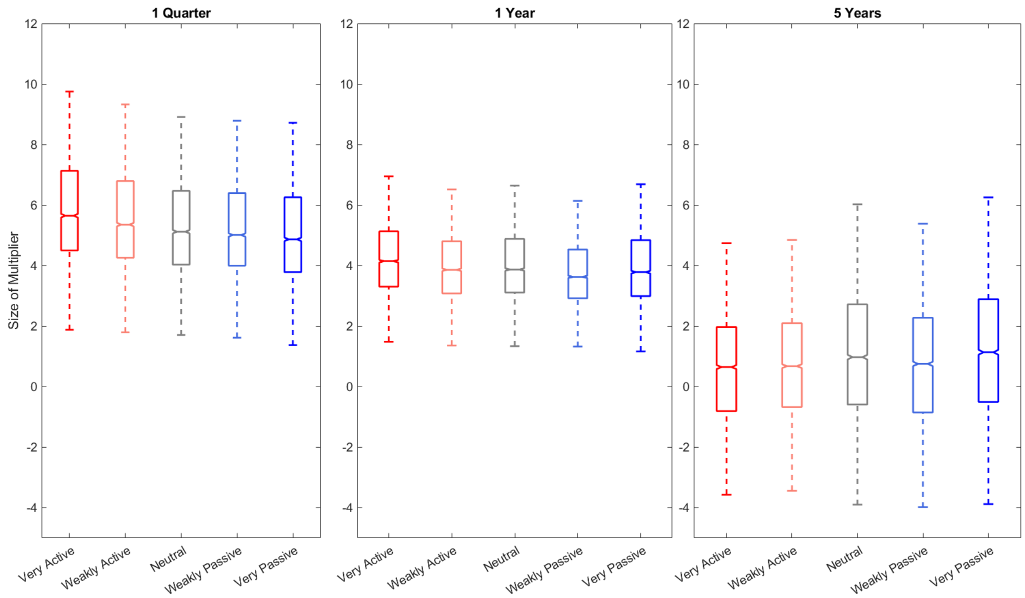


Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots and an updating regression. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. Estimated multipliers decrease with time but do not depend on the initial policy regime.

We find little evidence that the government spending multiplier depends on the shock size. Regardless of the shock size, the multiplier estimate is similar to our main exercise: the posterior median of the multiplier estimate decreases over time from above five after one quarter to around one after five years. We do not find any particular deviation in the response of the monetary policy regime after the shock to that from our main exercise shown in Section ??.[22]

[22]Results are available upon request.

Figure C.12.: Estimated Multipliers across Monetary Policy regimes for small Government Spending Shock



Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots and an updating regression. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. Estimated multipliers decrease with time but do not depend on the initial policy regime.

Finally, we present the results of a contradictionary government spending shock of size of one standard deviation. Figure **??** shows that following a contractionary government spending shock, the central bank responds quickly. The response of the monetary policy regime after the shock is different from that in our main exercise. Here, the monetary policy regime does not converge to a "very actvive" policy but to a "weakly active" - "neutral" policy. If the monetary policy regime after five years is less active than in our main exercise and the conventional wisdom in the literature exhibit some truth about the multiplier, we should expect that the magnitude of the multiplier after five years is larger than in our main exercise, even if it does not depend on the initial monetary policy regime within the five-year period. However, Figure **??** illustrates that our estimates do not support this claim. The posterior median after five years is around unity regardless of whether we consider a expansionary shock (leading to a “very active” policy after five years) or a contractionary shock (with a “weakly active”-“neutral” regime after five years).

Figure C.13.: Response of the Monetary Policy Regime for a contractionary Government Spending Shock

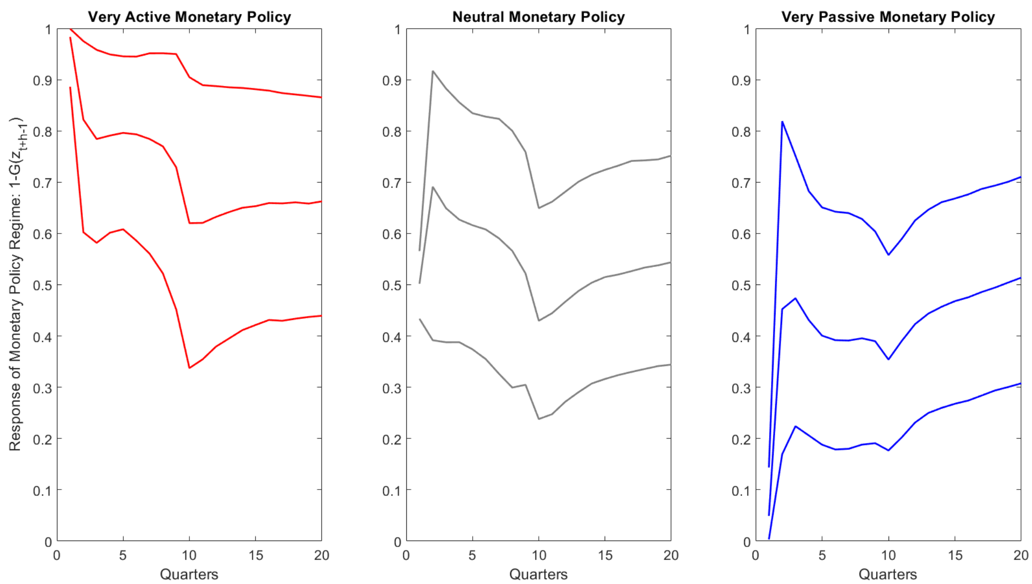
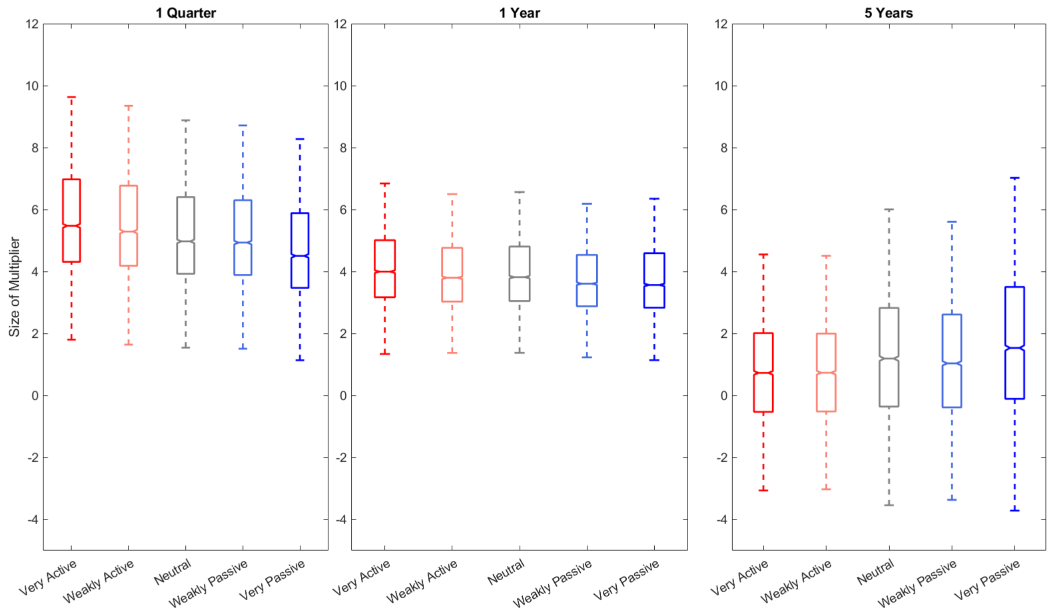


Figure shows the evolution of $1 - G$ after a contractionary government spending shock when monetary policy is initially “very active”, “neutral” and “very passive” regime. Regardless of the initial regime, monetary policy converges quickly to an “weakly active” or “neutral” regime.

Figure C.14.: Estimated Multipliers across Monetary Policy regimes for a contractionary Government Spending Shock



Note: Figure shows the estimated multiplier distributions one quarter and one and five years after the shock across initial monetary policy regimes using boxplots and an updating regression. The middle line and the box present the posterior median and the corresponding 50 percent credible bands. The upper and lower lines correspond to the highest and lowest value of the distribution that is not considered an outlier. Estimated multipliers decrease with time but do not depend on the initial policy regime.

D A narrative History of Monetary Policy

In this Section, we provide a narrative perspective about the history of monetary policy since 1954. The key goal is to develop a better understanding of why monetary policy has changed over time and to support our empirical estimation of monetary policy in Figure **??**. The section follows closely **?** and **?**. The authors analyze government reports such as Minutes and Transcripts of Federal Open Market Committee, Annual Reports of the Board of Governors of the Federal Reserve System and the Congressional testimony of the Feds chairman. They conclude that changes in monetary policy mostly occurred because the chairman of the Fed and/or other FOMC members changed their beliefs about whether inflation has negative long-run consequences, their estimate of the natural rate of unemployment and/or the responsiveness of inflation to economic slack. In Figure **??**, we combine the narrative results with our estimated history of monetary policy.

- William McChesney Martin Jr. was the chairman of the Fed between April 1951 and January 1970. **?** describe Martin as having similar beliefs about monetary policy as Paul Volcker and Alan Greenspan. Martin believed that high inflation was harmful in the long-run and that monetary policy should respond to bad economic conditions.
- The Fed lowered nominal interest rates substantially in response to the 1953/54 and to the 1957/58 recessions. In Figure **??**, our measure of monetary policy activism takes a value close to zero at the beginning of our sample indicating that monetary policy has been very passive during the late 1950s.
- Following the 1957/58 recession, inflation started to raise. The Fed responded via extreme monetary tightening. **?** suggest calling this period the *Martin Disinflation*. $1 - G(z_{t-1})$ in Figure **??** increases substantially in 1959.
- In the 1960s, the Fed changed their views and adopted "New Economics". In particular, the Fed believed that there was a long-run trade off between inflation and unemployment and that inflation would be low even for low levels of unemployment. Consequently, the Fed loosened its policy and did not tighten monetary policy during the second half of the 1960s even when output growth was high and inflation was increasing.

- At the end of Martin's tenure, the Fed returned to the natural rate framework but kept their optimistic view about the economy. In late 1968, the Fed tightened monetary policy substantially to combat increasing inflation. In 1968, $1 - G(z_{t-1})$ increases significantly.

- Arthur Burns followed William McChesney Martin Jr. as the chairman of the Fed in February 1970. Initially, he continued Martin's beliefs about monetary policy but became later pessimistic about the responsiveness of inflation to economic slack. At the end of his term, Burns would return to his initial views.

- During the first half Burns' first year, the Fed lowered nominal interest rate substantially. Their optimistic estimate about the natural rate of unemployment led the Fed to assume that there is significant slack in the economy. $1 - G(z_{t-1})$ in Figure **??**, displays this change as well: the monetary policy regime becomes more passive.

- When inflation rates did not fall as expected, the Fed changed its views and became overly pessimistic about the responsiveness of inflation to economic slack. According to Fed beliefs at that time, raising interest rates to cause economic slack would have been inefficient. As a consequence, the Fed imposed price controls in August 1971, which temporarily lowered inflation.

- Price controls were removed in January 1973 and inflation started to rise again. In addition, the Fed conducted an expansionary monetary policy.

- In the mid-1970s, the Fed's pessimism about the responsiveness of inflation to economic slack, restored the central bank's belief about the effectiveness of conventional monetary policy interventions. In addition, the Fed followed a higher estimate of the natural rate which in turn restored the belief that economic slack can lower inflation.

- In 1974, the Fed conducted contractionary monetary policy even though output was already decreasing. The Fed wanted to reduce inflation and was willing to accept a recession. Our estimate of monetary policy displays this change as well: $1 - G(z_{t-1})$ increases in the beginning of 1974.

- Due to increasing unemployment rates, the Fed lowered nominal interest rates in the winter of 1974/75. Monetary policy remained expansionary until the end of Burns' tenure in February 1978. Our model replicates this change: the value of $1 - G(z_{t-1})$ decreases in the winter of 1974/75 and remains high until 1979.

- William Miller would follow Arthur Burns to become the Fed's chairman between March 1978 and September 1979. In the following, the Fed became more optimistic about the natural rate of unemployment and believed monetary policy is ineffective to combat inflation: even though the Fed worried about high inflation during the late-1979s, the Fed's views on the responsiveness of inflation to slack and their high estimate of the natural rate prevented the Fed to tighten monetary policy.

- Paul Volcker became the chairman of the Fed in August 1979. The views about monetary policy changed fundamentally and remained the same during his chairmanship and under his successor Alan Greenspan: (i) high inflation has strong negative long-run consequences and little benefits, (ii) inflation responds to economic slack and (iii) their estimate of the natural rate was higher than previously assumed.

- In response to high inflation in the late 1970s, the Fed tightened monetary policy substantially which is believed to have caused the 1981/82 recession. Because of their high estimate of the natural rate, the unemployment rate necessary to reduce inflation was also high. According to our model, this change is the largest during our sample period. $1 - G(z_{t-1})$ increases from almost zero to almost one during a period of three years (1979 - 1982).

- Alan Greenspan replaced Paul Volcker as chairman of the Fed in August 1987 and served until January 2006.

- In response to the 1990/91 recession, the Fed lowered nominal interest rates. Our estimate of $1 - G(z_{t-1})$ changes from one to almost zero.

- Puzzle in the second half of the 1990s: **?** report that during the second half of the 1990s, inflation did not rise despite a long-lasting expansion. Greenspan argued that the economy became more competitive. Firms would rather cut costs than increase prices. In addition, **?** say that the Fed left real interest rates unchanged. According to our estimates, however, the Fed changed their responsiveness to inflation substantially. $1 - G(z_{t-1})$ decreases from almost one to zero and is very active until 2001.

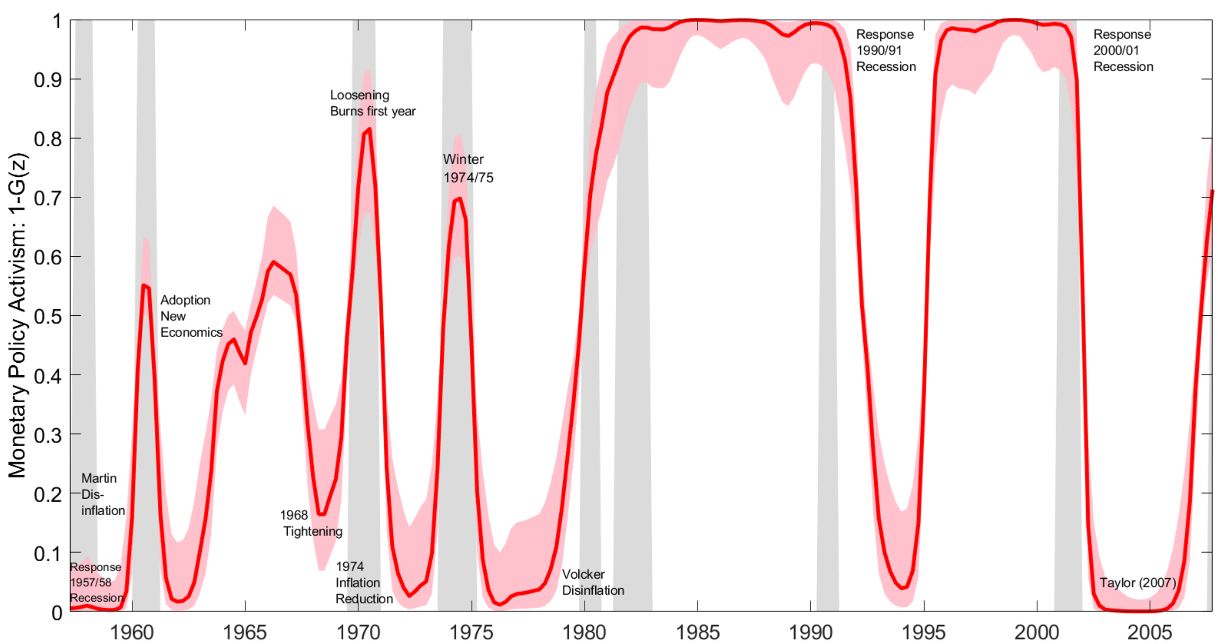
- The Fed loosened monetary policy in response to the 2000/01 recession. We estimate that the policy regime changed from being very active to being very passive.

- **?** argued that the Fed deviated substantially from the Taylor Principle between 2002 and 2005. He concludes that this deviation contributed enormously to the housing bubble, which led to the Financial Crisis in 2008. Our model replicates this behavior as well. G is equal to one with very little uncertainty between 2002 and 2005.

- Ben Bernanke followed Alan Greenspan in February 2006.

- Janet Yellen replaced Ben Bernanke as the Fed's chairman in February 2014.

Figure D.1.: Evolution of Monetary Policy between 1954 and 2008



Note: Figure show the median of the posterior distribution of G, along with the 68 percent credible bands. The grey bar represent the NBER recessions. The Figure combines our estimated evolution of monetary policy with narrative evidence given by **?**.