Endogenous Monetary-Fiscal Regime Change in the United States*

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Abstract

We estimate U.S. monetary and fiscal policy *regime* interactions in a regime switching model where regimes are represented by endogenous latent policy factors. Policy regimes interact strongly: shocks that switch one policy from active to passive tend to induce the other policy to switch from passive to active, consistent with existence of a unique equilibrium. In some periods, though, both policies are active and government debt grows rapidly. We also observe relatively strong interactions between monetary and fiscal policy regimes after the recent financial crisis. Latent policy regime factors exhibit patterns of correlation with macroeconomic time series, suggesting that policy regime change is endogenous.

JEL Classification: C13, C32, C38, E52, E58, E63

Key words and phrases: monetary and fiscal policy interactions, endogenous regime switching, adaptive LASSO, time-varying coefficient VAR, factor augmented VAR.

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1 Introduction

The recent financial crisis and great recession have generated growing interest in the interaction of monetary and fiscal policies. Theoretical analyses of policy interaction focus on how monetary and fiscal regimes can jointly accomplish the tasks of price level determination and debt stabilization (Sargent and Wallace (1981), Wallace (1981), Aiyagari and Gertler (1985), Sims (1988) and Leeper (1991)).

The conventional policy regime has central banks stabilize inflation by systematically raising nominal interest rate more than one-for-one with inflation while the fiscal authority adjusts taxes or government spending to assure fiscal solvency. An alternative regime reverses the policy roles: fiscal policy determines the price level, and monetary policy stabilizes debt. By making primary surpluses insensitive to debt, the price level adjusts to equate the real value of outstanding debt to the expected discounted present value of primary surpluses. Monetary policy passively permits the necessary change in the current and future price levels to occur by responding weakly to current inflation. It is convenient to label the conventional regime M (active monetary/passive fiscal) and the alternative regime F (passive monetary/active fiscal) (Leeper (1991)). Both of these regimes are consistent with the existence of a determinate bounded rational expectations equilibrium.

Although economic theory emphasizes monetary and fiscal *regimes*, most empirical studies focus on dynamic patterns of correlation among policy *variables*.[1] But correlations among policy variables can tell us nothing about interactions between policy regimes. Other work studies exogenous switching of monetary and fiscal regimes.[2] Exogenous regime change, though, is silent about a causal mechanism which connects changes in monetary regime to switches in fiscal regime.

This paper is a first step toward bringing empirical work on regime change closer to theory. We estimate endogenous regime switching monetary and fiscal policy rules that describe purposeful policy behavior in which policy rule coefficients respond to the state of economy systematically. And we examine policy regime interactions using policy regime factors which determine policy regimes explicitly in our policy rules.

The paper applies econometric techniques that Chang et al. (2017) develop to simple monetary and fiscal rules. Monetary policy follows a simplified Taylor-type rule that makes the nominal interest rate depend on inflation and a monetary disturbance. Fiscal policy adjusts tax revenues in response to current government purchases, the real market value of outstanding government debt, and a fiscal disturbance. Policy regimes are determined by an endogenous autoregressive latent policy factor and a threshold. Regime change is triggered whenever the latent policy regime factor crosses the estimated threshold.

Endogenous regime change arises from two aspects of the econometric structure: (1) choices of policy instruments depend on systematic responses to target variables plus a disturbance that

[1] See, for example, King and Plosser (1985), Melitz (1997, 2000), von Jagen et al. (2001), Muscatelli et al. (2002) and Kliem et al. (2015).

[2] For example, Favero and Monacelli (2005), Davig and Leeper (2006b), Gonzalez-Astudillo (2013) and Bianchi and Ilut (2014).

reflects how policy choice reacts to non-target information; (2) policy parameters are functions of a latent policy factor whose dynamic evolution depends on both past policy disturbances and an exogenous shock. For example, if at time t policy sets the instrument above the level that the systematic response to the targets implies, this positive disturbance predicts future changes in the latent factor and, therefore, in policy regime. Two economic effects come from such a disturbance. First, there is the direct effect of a higher realization of the policy instrument. Because the disturbance carries with it information about future realizations of the systematic reactions of policy to targets, a second effect arises from changes in private agents' expectations of policy regime.

This setup has a natural interpretation in terms of actual policy behavior. Rarely do policy makers choose to shift discretely to a new regime. Instead, policy choices typically evolve from one regime to another, an evolution captured by the dynamics of the latent factor. On the other hand, the econometric method is flexible enough to also handle sudden changes in regime that are triggered by unusually large realizations of the policy disturbance or the exogenous shock to the latent factor.

We estimate models for monetary and fiscal policies separately.[3] We use the likelihood-based filter that Chang et al. (2017) develop to examine likelihood profiles that ensure a global maximum. We find two interpretable policy regimes for monetary and fiscal policy rules (active/passive) according to Leeper (1991), between which policy rules fluctuate. Estimates undercover strong evidence of endogeneity, rejecting the null of no endogeneity at 1% significance level.

The most interesting and novel implications of this work come from studying dynamic interactions between the two policy regime factors and among regimes and macroeconomic variables. This analysis sheds light on how monetary policy's choice of its rule may influence fiscal policy's choice of its rule (and vice versa). Every central bank takes the stance of fiscal policy into account in its policy choices.[4]

We analyze the dynamic interactions of the policy regime factors in a time-varying coefficient VAR (TVC-VAR) model. Policy interactions have changed historically:

- After a shock to the monetary policy factor that makes the regime passive, the regime tends to remain passive, suggesting stability in policy behavior. That stability is strongest over a sample that includes the 1980s, a time when most observers believe U.S. monetary policy was sharply focused on inflation control. Except during the 1950s, that monetary regime shock drives fiscal policy toward an active to produce a passive monetary/active fiscal combination that theory suggests delivers a determinate, well-behaved equilibrium.

- A negative shock to the fiscal policy factor that makes the regime active is followed by persistently active fiscal behavior. Monetary policy's response to the fiscal disturbance, however,

[3]Treating policies as separate should be understood as illustrative to demonstrate clearly the value-added of the technique before tackling a more plausible, but significantly more complex, system of equations.

[4](King, 1995, p. 171) famously wrote: "Central banks are often accused of being obsessed with inflation. This is untrue. If they are obsessed with anything, it is with fiscal policy." Analogously, fiscal authorities routinely project interest rates when reaching debt-management decisions.

varies over the sample. In the 1950s, monetary policy tends to become active. The doubly active policy mix, according to theory, stabilizes neither inflation nor debt. Sample periods that include data from the 1990s or more recently find monetary policy reacting by becoming passive to put the economy in a stabilizing policy regime.

- During the 1990s and 2000s, policy regimes were mostly active monetary/passive fiscal. But following a negative shock to the fiscal policy factor that makes the regime active, monetary policy tends to become passive even during periods when the prevailing mix is active monetary and passive fiscal. This supports work that argues that the fiscal theory is operating whenever economic agents believe it is possible for fiscal policy to become active, even when the rules in place at a given moment would suggest that Ricardian equivalence should hold if regime were fixed (Davig et al. (2004) and Davig and Leeper (2006b)).

We investigate the interactions between regimes and macroeconomic variables in various aspects. We explain which macro variables mainly explain the regime switching in the policy rules and how policy regime factors are related to the state of the macroeconomy. Adaptive least absolute shrinkage and selection operator (adaptive LASSO) permits us to examine a large set of variables that might explain the dynamics of policy regime factors. There are some variables which are commonly selected in both MP and FP regime factors including debt to GDP ratio, bank prime loan rate, privately owned housing starts, all employees and output gap. More important finding from the adaptive LASSO analysis is that debt to GDP ratio is selected importantly for the MP regime factor and spread of long term and short term interest rates is chosen for the FP regime factor with larger estimated coefficients. This result can be regarded as an indirect evidence of policy interactions.

To estimate how key macroeconomic variables affect the policy regime factors, we use the factor-augmented VAR (FAVAR) that Bernanke et al. (2005) introduced. Policy regime factors have important predictive power for the key macro variables and dynamic impacts that accord well with a *priori* expectations. Shocks to non-policy regime factors, especially those that embody real activity, generate movements in policy regime factors that are theoretically plausible.

The rest of the paper is organized as follows. In Section 2, we introduce our endogenous regime switching policy rules and provide economic interpretations on our model specification. We also estimate endogenous regime switching monetary and fiscal policy rules and give explanations for the plausibility of estimates. Section 3 explains how monetary and fiscal policy rules have interacted historically using extracted policy regime factors and the time varying coefficient VAR. Section 4 shows potential channels between policy regime factors and macroeconomic variables using the shrinkage regression (adaptive LASSO), Factor Augmented VAR (FAVAR) and VAR analysis. Section 5 reports some robustness results, including the presence of stochastic volatility, estimation errors from the estimated latent policy factors and the zero lower bound. Section 6 concludes the paper, and Appendix collects results from the additional analyses, figures, tables and data description.

1.1 Contacts with Literature

Previous empirical results focused on a correlation among policy variables have been mixed. King and Plosser (1985) study the relationship between fiscal deficits and inflation using U.S. data and find no empirical evidence of a relationship. Melitz (1997, 2000) investigates the interaction between monetary and fiscal policies over the business cycle using a data set for 19 OECD countries and shows that the two policies tend to move in opposite directions. Kliem et al. (2015) estimate the low-frequency relationship between primary deficits over debt and inflation in a time-varying VAR model for U.S. data. They find that the relationship between inflation and primary deficits over debt is mostly positive before 1980 and insignificantly different from zero after 1980.

Recent work explores dynamic interactions between monetary and fiscal *regimes* using exogenous regime switching models. Favero and Monacelli (2005) consider monetary and fiscal regime switching and find that regime switches in monetary and fiscal policy rules do not exhibit any degree of synchronization. Davig and Leeper (2006b) consider monetary and fiscal regime switching using U.S. data. After imposing the estimated policy process on a conventional calibrated dynamic stochastic general equilibrium (DSGE) model with nominal rigidities, they provide an interpretation of post-war macro policies. Gonzalez-Astudillo (2013) considers time variation in the policy rules by specifying coefficients that are logistic functions of correlated latent factors and finds that there is a non-negligible degree of interdependence between policies. Bianchi and Ilut (2014) estimate a model for U.S. economy with monetary/fiscal mix changes and explain why inflation dropped in the 1980s in terms of the policy change.

There is work that estimates endogenous regime switching models—including Diebold et al. (1994) and Kim et al. (2008)—but their specification of endogeneity differs from ours. Diebold et al. (1994) consider a markov process that is driven by a set of observed variables. Kim et al. (2008) study a regime-switching model driven by an endogenous i.i.d latent factor with the threshold level determined by the previous state and possibly lagged value of the underlying time series.

2 Regime Switching Policy Rules

In this section, we introduce a new model for regime switching to better understand policy rules and their interactions. Our model relies on the endogenous regime switching model suggested in Chang et al. (2017) where regime switching is determined by an endogenous autoregressive latent factor. We consider the policy rule equation

$$y_t = x_t'\beta_{s_t} + u_t, \tag{1}$$

where y_t and x_t are respectively the policy instrument and the policy target variables believed to be considered by the policy makers at time t, β_{s_t} is the state dependent policy parameter which is defined more precisely below, and u_t signifies the policy disturbance measuring the deviation of policy instrument y_t from the policy rule $y_t^* = x_t'\beta_{s_t}$, and satisfies

$$\mathbb{E}\left[u_t \middle| s_t, x_t, \mathcal{G}_{t-1}\right] = 0, \tag{2}$$

which is imposed in our model and where $\mathcal{G}_{t-1}$ is the information available at time $t-1$ to the policy makers. We may view the policy disturbance u_t as the part of the instrument variable y_t that is not predicted by the policy target variables x_t. The policy disturbance u_t represents the multitude of all other factors that affect the policy making, such as the policy shocks and other policy concerns not measured by the policy target variables x_t, and hence it is not regarded as an exogenous shock from the perspective of the policy maker. Rather it represents systematic responses of the policy makers to the state of the economy, other than the aspects of the state already reflected in the policy target variables x_t included as the right-hand-side variables.

In our model, the state variable s_t determining the policy regime is specified as

$$s_t = 1\{w_t \geq \tau\},$$

with a latent policy factor w_t representing the internal information set used by a policy maker for her policy decision, and τ is a threshold parameter. The policy factor is assumed to evolve over time as

$$w_t = \alpha w_{t-1} + v_t,$$

where v_t and u_{t-1} are jointly i.i.d. normal with unit variance and $\text{cov}\,(u_{t-1}, v_t) = \rho$. The conditional distribution of v_t given u_{t-1} is normal with mean ρu_{t-1} and variance $1 - \rho^2$, and, therefore the presence of endogeneity dampens the variability of the policy factor shock v_t and consequently weakens the idiosyncratic component of v_t independent of u_{t-1}. We expect $\rho \neq 0$, so that we have a feedback channel in the policy rule (1).[5] A part of the policy disturbance u_{t-1} incurred in the previous period will affect the change in policy choice β_{s_t} in the current period through its endogeneity with the shock v_t to the current policy factor w_t that determines the current state s_t and policy regime. We may therefore infer from the degree ρ of endogeneity how much exogenous component is left in the policy factor, which may be interpreted as idiosyncratic considerations of policy makers beyond the information embedded in the past policy disturbance.

In our model with $\rho \neq 0$, we envision that policy behaves with discretion and at each period t it chooses policy parameter β_{s_t} and subsequently policy disturbance $u_t = y_t - x_t'\beta_{s_t}$. Policy choice of β_{s_t} depends on previous u_{t-1} at time $t-1$[6] and also on an independent component realized at the current period t. This means, of course, that policy's current choice of u_t influences future choices of β_{s_t} to introduce an element of constrained discretion to policy choice. More explicitly,

[5] Our estimation technique permits estimates of ρ close to zero, indicating that the endogeneity of regime change is weak.

[6] If we introduce nonzero correlation between v_t and further lags $u_{t-1}, \ldots$ of u_t, then the policy maker would consider $\beta_{s_{t-1}}, \beta_{s_{t-2}}, \ldots$ and extract policy disturbances $u_{t-1}, u_{t-2}, \ldots$.

we assume that β_{s_t} in the current period t is updated according to the policy choice

$$\beta_{s_t} = \underset{\beta}{\operatorname{argmin}}\, \mathbb{E}\left[(y_t - x_t'\beta)^2 \middle| \, s_t, x_t, \mathcal{G}_{t-1} \right], \tag{3}$$

where $\mathcal{G}_{t-1}$ is the information available at time $t-1$ to the policy makers, which includes entire history of policy instrument y, policy target variables x, and state variable s up to time $t-1$. This means that β_{s_t} minimizes the mean squared error loss incurred by policy disturbance at each time t conditionally on state s_t and target variables x_t at time t and all other information available to her at time $t-1$. Therefore, in particular, our state dependent policy choice in (3) is well formulated as a regression in (1) satisfying the usual orthogonality condition between regressor and regression error. Policy choice in (3) naturally entails policy rule in (1) above.

This is in sharp contrast with the conventional markov switching model, which assumes $\rho = 0$. Under this exogeneity assumption, there is no feedback channel in policy rule. Consequently, all past states and policy disturbances become irrelevant in setting a state dependent policy rule. In fact, in this case, we have

$$\beta_{s_t} = \underset{\beta}{\operatorname{argmin}}\, \mathbb{E}\left[(y_t - x_t'\beta)^2 \middle| \, s_t, x_t, \mathcal{F}_{t-1} \right],$$

where $\mathcal{F}_{t-1}$ only includes policy instrument y and policy target x observed at time $t-1$, excluding all other past policy rules and disturbances. In the existing literature, a wide class of regime switching policy rules is considered and analyzed by many authors (see, e.g., Davig (2004), Davig and Leeper (2006b), Favero and Monacelli (2005), Sims and Zha (2006), Gonzalez-Astudillo (2013) and Bianchi and Ilut (2014)). The major difference between our endogenous regime switching policy rules from the existing conventional regime switching policy rules is the endogenous structure in the regime switching.[7]

In what follows, we specify the endogenous regime switching models for monetary and fiscal policy rules, and subsequently estimate the models using the U.S. data. Finally, we consider the plausibility of our estimates based on narrative accounts of policy behavior.

[7] Davig and Leeper (2006a) consider an endogenous regime switching monetary policy model where the coefficients on inflation and output gap are specified as functions of the inflation threshold and lagged inflation in a New Keynesian model. Their model, however, excludes a possibility that the regime is driven by some unobserved economic fundamentals. Also, their model is calibrated and not directly comparable to ours.

2.1 Endogenous Regime Switching Model in Policy Rules

We consider a simple Taylor (1993) rule type monetary policy which makes the nominal interest rate, i_t, depend only on inflation, π_t:[8]

$$i_t = a_c(s_t^m) + a_\pi(s_t^m)\pi_t + \sigma^m u_t^m, \tag{4}$$

where s_t^m represents a state process specifying a binary state of regime in monetary policy at time t, and $s_t = 0$ and 1 are regimes which respond to the inflation weakly and aggressively respectively, and $a_j(s_t^m)$, $j = c, \pi$, are state dependent monetary policy parameters. u_t^m represents the monetary policy disturbance measuring the deviation of monetary policy instrument i_t from the monetary policy rule $i_t^* = a_c(s_t^m) + a_\pi(s_t^m)\pi_t$. We may let $s_t^m = 1\{w_t^m \geq \psi_m\}$, where w_t^m is a latent monetary policy factor representing internal information set used by a central bank for her policy decisions and ψ_m is a threshold. Monetary policy makers' information set is assumed to be larger than that of private agents and econometricians, and not directly observable to outsiders and, therefore it is modeled as a latent factor. We allow for two regimes in policy rule coefficients specified as $a_j(s_t^m) = a_{j,0}(1 - s_t^m) + a_{j,1}s_t^m$ for $j = c, \pi$, and a regime switching occurs when monetary policy factor w_t^m crosses threshold ψ_m.[9]

The monetary policy factor w_t^m drives the regime change in our model and is assumed to evolve over time as an autoregressive process $w_t^m = \alpha_m w_{t-1}^m + v_t^m$, with autoregressive coefficient α_m indicating the degree of persistency in regime changes. Moreover, monetary policy disturbance u_t^m and shock v_t^m to policy factor are assumed to be jointly i.i.d. normal as

$$\begin{pmatrix} u_{t-1}^m \\ v_t^m \end{pmatrix} = \mathbb{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_m \\ \rho_m & 1 \end{pmatrix} \right). \tag{5}$$

In light of our earlier discussion, we may view monetary policy disturbance u_t^m as the part of monetary policy instrument, nominal interest rate i_t, that is not predicted by monetary policy target variable, inflation π_t. Hence, u_t^m is not an exogenous shock in the conventional sense from the policy maker's point of view. Rather it represents all other factors such as monetary and

[8]There exists significant variation in policy rule specification. According to Rotemberg and Woodford (1999), standard Taylor (1993) specification is nearly optimal in the class of models considered in their paper. Leeper and Roush (2003), Ireland (2004), and Sims and Zha (2006) argue that allowing money growth to enter the monetary policy rule is important for identifying policy behavior. Davig and Leeper (2006b) include a dummy variable to absorb the variability in interest rates induced by credit controls in the second and third quarters of 1980. We seek to simplify the model to highlight the new endogeneity channel in regime switching policy rules in this paper. In our specification, we exclude output gap because of its potential measurement error and a substantial data revision emphasized in Kozicki (2004).

[9]Our models can be easily extended to allow for multiple regimes, but two states are considered enough to characterize policy coefficient switching in previous literature. According to Sims and Zha (2006), heteroskedastic errors are essential for fitting the U.S. data, and many authors also consider regime switching in volatility. Our approach may also allow to estimate policy rules with unsynchronized parameter and volatility switchings using a modified version of the filter by Chang et al. (2017). In this paper, we consider coefficient switching only to focus on policy interactions.

other structural shocks and their entire history that may affect monetary policy decision but not measured by the target variable inflation. Central banks may give weights to different economic conditions including commodity prices, sluggish labor market development, stock market and stance of fiscal policy for a monetary policy decision with the occasion. Our interpretation of u_t^m implies a view that the Fed's primary objective is to achieve low and stable inflation over the medium term[10] and at the same time, the Fed has reacted to emerging economic states purposefully and intermittently.[11]

Our specification of endogeneity in (5) explicitly allows for the aforementioned feedback channel in monetary policy rule. A part of the monetary policy disturbance u_{t-1}^m incurred in the previous period will affect the change in policy choice $a_\pi(s_t^m)$ in the current period through its endogeneity with the shock v_t^m to the current monetary policy factor w_t^m that determines the current state s_t^m and monetary policy regime. We may therefore infer, from the degree of endogeneity ρ_m, how much exogenous component is left in the monetary policy factor, which may be interpreted as idiosyncratic considerations of central banks beyond the information embedded in the past monetary policy disturbance. We may observe that even the monetary policy regime changes are determined by the state of the economy, but the timing of regime changes may be not systematically determined to some degree. For example, monetary policy regime change in 1980's may be an endogenous response to the state of the economy, high inflation leading to the appointment of inflation fighting central bank governors, and the timing of this monetary regime change might not be based on economic status only, possibly influenced by political aspects.

Our specification for endogenous regime switching in monetary policy rule appears natural for policy analysis and subsequent interpretations. As in reality, policy authorities may adjust their policy behaviors based on the broad economic outlook and their own predictions about future economic states as well as on the entire history of policy instruments and targets, and we may naturally interpret the latent monetary policy factor as an internal information set used by the policy makers. The feedback channel established by endogeneity between next period policy regime factor and current policy disturbance in our model provides a sensible scheme with which policy makers may effectively utilize multiple sources of information on the economy for a purposeful policy, and thereby introduce constrained discretion to policy choice.

Contrary to monetary policy, there is no widely accepted specification for the fiscal policy.[12] We specify fiscal policy rule that links revenues net of transfer payments τ_t to current government

[10] See transcript of Federal Open Market Committee (September 17, 2015) for this terminology.

[11] (Taylor, 1993, p. 202-203) states "What is perhaps surprising is that this rule fits the actual policy performance during the last few year remarkably well...There is a significant deviation (of the FFR to policy rule) in 1987 when the Fed's response to the crash in the stock market by easing interest rates." This statement supports our interpretation on u_t^m.

[12] There are some studies of estimated fiscal rules including Bohn (1998), Taylor (2000), Fatas and Mihov (2001), Auerbach (2003), Cohen and Follette (2005), Ballabriga and Martinez-Mongay (2005), Claeys (2004), Davig (2004) and Favero and Monacelli (2005).

spending purchases g_t and debt held by public b_{t-1}. Our fiscal policy specification is given as

$$\tau_t = \beta_c(s_t^f) + \beta_b(s_t^f)b_{t-1} + \beta_g(s_t^f)g_t + \sigma^f u_t^f, \tag{6}$$

where s_t^f represents a state process specifying a binary state of fiscal policy at t with $s_t = 0$ and 1 representing regimes which respond to the level of debt weakly and aggressively, and u_t^f signifies fiscal policy disturbance. As in our model for monetary policy, we may let $s_t^f = 1\{w_t^f \geq \psi_f\}$, and use it to define our state dependent fiscal policy parameters as $\beta_j(s_t^f) = \beta_{j,0}(1 - s_t^f) + \beta_{j,1}s_t^f$ for $j = c, b, g$, and assume that latent fiscal policy factor w_t^f follows AR(1) dynamics $w_t^f = \alpha_f w_{t-1}^f + v_t^f$, driven by fiscal policy shock v_t^f, and that v_t^f and previous fiscal policy disturbance u_{t-1}^f are jointly normal with unit variance and $\text{cov}(u_{t-1}^f, v_t^f) = \rho_f$. As in the monetary policy rule specification, we allow for two states in fiscal policy coefficients, and may also interpret w_t^f and endogeneity parameter ρ_f in fiscal policy regime changes exactly as in our monetary policy rule.

2.2 Estimation Results

We use quarterly U.S. data from 1949:1 to 2014:2. To estimate the monetary policy rule (4), we define π_t to be inflation rate over contemporaneous and prior three quarters as in Taylor (1993) and obtain inflation each period as log difference of GDP deflator. For nominal interest rate i_t we use three-month Treasury bill (T-bill) rate in the secondary market. We use T-bill rate instead of federal funds rate (FFR) mainly because FFR is available publicly only from 1954:1. T-bill rate is highly correlated with FFR with sample correlation 0.988 over the period 1954:1-2014:2, and available for a longer period since 1949:1. Using T-bill rate allows us to study meaningful regime changes in monetary and fiscal policy rules before 1954 which include important historic episodes such as Treasury Accord of March 1951 leading to passive monetary policy and the wartime fiscal financing for Korean war leading to active fiscal policy.

All fiscal variables are for the federal government only. τ is federal tax receipts net of total federal transfer payments as a share of GDP, and b is market value of gross marketable federal debt held by public as a share of GDP which may represent the debt burden faced by U.S. government more accurately than par value,[13] and g is federal government consumption plus investment expenditures as a share of GDP.[14] To estimate (6) we use average debt-output ratio over previous four quarters as a measure of b_{t-1}.

The estimation tools and strategy for the conventional markov switching models are usually based on the simple markov chain structure of the state variable. In our endogenous switching models, however, a state of policy rule, s_t^j, $j = m, f$ alone is not a markov chain due to the feedback channel created by endogeneity between the policy disturbances and policy factor shocks,

[13] We use the measure provided by Federal Reserve Bank of Dallas

[14] Monetary policy variables are obtained from Federal Reserve Bank of St. Louis, Economic Data-FRED, and fiscal policy variables from NIPA Table 3.2 (for τ, g) and Federal Reserve Bank of Dallas, U.S. Economic Data and Analysis (for b).

and hence, the conventional markov switching filter cannot be used to estimate our endogenous regime switching model (4) or (6). However, s_t^j, $j = m, f$ does have markov property jointly with observed policy instruments i_t or τ_t. Exploiting this joint markovian structure, Chang et al. (2017) develop a modified markov switching filter to evaluate likelihood in the presence of endogeneity, and we follow their approach to estimate our endogenous monetary and fiscal policy rules (4) and (6) together with a numerical optimization method.

To ensure that we find the global maximum for our nonlinear likelihood functions, we follow the profile likelihood estimation strategy with respect to autoregressive coefficient of latent policy factor α_i, $i = m, f$, and endogeneity parameter ρ_i, $i = m, f$, as suggested in Chang et al. (2017). For profiling, we fix α_i at a value ranging from 0.1 to 0.9 and ρ_i from -0.9 to 0.9 with 0.1 increment. For each pair of α_i and ρ_i, we find a unique maximum of the likelihood function for both policy rules.[15] Figures 1 and 2 show that a global maximum is found at around $\alpha_i = 0.9$ and $\rho_i = 0.9$ for both monetary and fiscal policy rules, while Tables 1 and 2 report the maximum likelihood estimates for endogenous regime switching monetary and fiscal policy rules. We also extract monetary and fiscal policy factors w_t^m and w_t^f from the maximum likelihood estimation of our policy rules.

Leeper (1991) provides a simple model in which the price level is jointly determined by monetary policy (MP) and fiscal policy (FP) depending upon parameter values of MP and FP. Following terminologies introduced in Leeper (1991), active monetary/passive fiscal regime (AM/PF, for short) means the conventional view that central banks adjust the policy interest rate aggressively in response to inflation while the fiscal authority passively adjusts taxes and spending to ensure the fiscal solvency. An alternative view, the passive monetary/active fiscal regime (PM/AF) is that the fiscal policy nails down the real value of debt and the price level by making taxes unresponsive to debt while monetary policy passively permits jumps in the price level that stabilize debt. We also use AM/PF and PM/AF to interpret our estimation results.

We may infer from the estimates of state dependent parameter on inflation α_π given in the shaded area of Table 1 that monetary policy switches between active with $\alpha_m > 1$, when it responds strongly to inflation by more than one-to-one, and passive with $0 \leq \alpha_m < 1$, when it responds weakly to inflation. In our model, policy regime is determined depending upon whether the extracted monetary policy factor w_t^m is above the estimated threshold ψ_m. Therefore, we may use the phrase 'active (passive) monetary policy regime' can be used interchangeably with 'monetary policy factor is above (below) estimated threshold'. The estimate of AR coefficient of monetary policy factor α_m is 0.983, indicating strong persistency of monetary policy regime, and the estimate of endogeneity parameter ρ_m is 0.999, showing a strong and clear evidence of the existence of endogeneity in monetary policy regime determination.

Before we interpret our estimated monetary policy factor, we summarize the feedback channel from current policy disturbance u_t^j to policy factor next period w_{t+1}^j, $j = m, f$ and finally to policy

[15]We try 8-23 sets of initial values for all other parameters to find the maximum of the likelihood function. Initial values for policy coefficients are chosen based on economic theory and estimates reported in the literature. We consider a wider range of initial values for thresholds (ψ_i), $i = m, f$.

regime next period in the chart below.

$u_t^m > 0 \Rightarrow w_{t+1}^m \uparrow$	More likely to have active MP in future Less likely to have passive MP in future
$u_t^f > 0 \Rightarrow w_{t+1}^f \uparrow$	More likely to have passive FP in future Less likely to have active FP in future

Our estimates from monetary policy rule imply that a positive monetary policy shock u_t^m in current period would forecast a higher monetary policy factor, which in turn implies that monetary policy is more likely to be active (less likely to be passive) in the next period. For example, if news contained in commodity prices portends higher future inflation but does not yet affect inflation today, this positive shock would raise nominal interest rate above the level that current inflation predicts. A positive policy shock forecasts higher latent policy regime factor, which means a monetary authority would respond more aggressively to inflation in the next period.

The shaded areas in Table 2 show that fiscal policy switches between passive and active by responding more than the quarterly real interest rate to debt or responding negatively to debt. Here we use the phrase 'active (passive) fiscal policy regime' interchangeably with 'extracted fiscal policy factor below (above) estimated threshold'. Active fiscal policy reacts weakly to debt and responds strongly to government spending, through by more than one-to-one. Passive fiscal policy reacts strongly to debt. The estimate of α_f is 0.97, implying that fiscal policy regime is also persistent but less persistent than monetary policy regime. We also find the presence of strong endogeneity in fiscal policy regime switching from $\rho_f = 0.999$. Our estimates from fiscal policy rule imply that when there exists a positive fiscal policy shock u_t^f, this positive fiscal policy shock forecasts higher fiscal policy factor, which means a fiscal authority is more likely to have passive FP in future (less likely to have active FP in future).

Table 3 presents the implied average policy instruments and target variables conditional on estimated regime. We observe that the average real interest rate is higher in the active MP regime than in passive MP regime. Possibly, state dependent inflation target rate explains the difference between average real interest rates by regime. In linear models, only the coefficient on inflation matters for the nature of the MP regime, but it is noteworthy that there is more to the regime change than simply the coefficient on inflation. Also, despite a higher average level of debt, average tax revenues are lower in the active FP regime than in passive FP regime, and it reaffirms how fiscal policy has behaved in active regime on average.

For both monetary and fiscal policy rules, we also observe that the maximum log likelihood from the endogenous switching model is larger than that from the corresponding exogenous switching model which has been considered frequently in previous empirical studies. We test for the presence of endogeneity in regime switching using the likelihood ratio test and clearly reject the null of no endogeneity at less than 1% significance level.

2.3 Plausibility of Estimates

We now examine the plausibility of our estimated policy rules in two ways—one based on the estimated policy parameters and the other on the estimated state distributions. First of all, we note that our estimated policy rules fluctuate between theoretically interpretable regimes. Monetary policy fluctuates between active periods with the estimated policy parameter a_π satisfying Taylor principle $a_\pi > 1$, and passive periods with $0 \leq a_\pi < 1$. Our estimated passive fiscal policy regime responds to debt strongly with a policy coefficient that exceeds most of the quarterly real interest rate estimates. Under passive fiscal policy, any increase in debt brings forth further surpluses that rise by real debt service plus a bit more to gradually retire the newly-issued debt. Active fiscal policy, on the other hand, makes taxes relatively insensitive to debt and according to our estimation of the policy parameter on debt, tax becomes even lower when debt increases.

Our estimated state distributions also seem quite consistent with narrative accounts of policy history.[16] Figure 3 plots the time series of extracted monetary policy regime factor and the estimated threshold. As mentioned earlier, monetary policy regime is identified to be passive when the level of MP regime factor is below the threshold. Figure 4 shows the estimated passive monetary policy regimes (shaded areas) and historical data for T-bill and inflation rates. Except for the three brief periods in 1950:1-1950:2, 1959:3-1960:4, 1973:1-1974:2 and a longer period in 1962:1-1970:4, monetary policy was passive until the Fed changed operating procedures in October 1979 when monetary policy became active. After 1980, monetary policy has been mostly active except for the two passive periods immediately after two recessions in 1991 and 2001. For an extended period during the recent “jobless recoveries”, monetary policy continued to be less responsive to inflation well after the official troughs of the downturns. The passive episode after 1991 recession became active when the Fed launched its preemptive strike against inflation in 1994. After the 2007-2008 financial crisis, monetary policy has become passive.

These results are broadly consistent with previous empirical findings. At the beginning of our sample until Treasury Accord of March 1951, Federal Reserve policy supported high bond prices by keeping interest rates lower even though consumer price index rose, indicating a passive monetary policy. Through Korean War, monetary policy largely accommodated the financing needs of fiscal policy (Ohanian (1997) and Woodford (2001)). According to our estimation, 1950s was mostly passive except for two brief periods at the very beginning and end, but Romer and Romer (2002) offer a narrative evidence that the Fed objectives about the economy in 1950s were very much like those in 1990s, particularly in its great concern about inflation. To support their narrative evidence, Romer and Romer (2002) estimate a forward-looking Taylor rule for the period 1952:1-1958:4, and conclude that monetary policy was active during this period, and the response of the interest rate to inflation was 1.178 with a large standard error 0.876. Our estimate of this response coefficient is 0.66, which is well within one standard error of the point estimate by Romer and Romer (2002).

[16]Narrative evidence draws on Pechman (1987), Poterba (1994), Stein (1996), Steuerle (2002), Romer and Romer (2004), and Yang (2007).

Therefore, our estimate is not inconsistent with theirs; however, the extracted monetary policy factor is below the estimated threshold, which identifies this period as a passive regime. The Fed might have intended to be aggressive against inflation during this period; however it appears not to have acted to prevent the 1955 inflation.[17] The brief burst of active monetary policy late in 1959 is also consistent with the finding by Romer and Romer (2002) that the Fed raised real interest rate in this period to combat inflation. During the entire 1960s, we find that monetary policy regime was active, which differs from previous empirical findings.

Since 1979, monetary policy was active except for two short periods following the recessions in 1991 and 2001. Consistent with these historical episodes, our estimates indicate that monetary policy was passive during 1993:1-1994:1 and 2002:1-2006:2. As discussed in Davig and Leeper (2006b), there were prevailing concerns about low real interest rates and monetary policy behavior in the early 1990s and 2000s. During policy deliberations at March 1993 FOMC meeting which took place after the federal funds rate had been at 3 percent for several months, Governors Angell, LaWare, and Mullins expressed concern that the Fed was keeping the rate low for too long, and Governors Angell and Lindsey dissented on the vote to maintain the funds rate at 3 percent, see Board of Governors of the Federal Reserve System (1993a). Six months later, Governor Mullins analogized 1993 to 1970s as another period in which perhaps short rates were not appropriately set to track inflation in Board of Governors of the Federal Reserve System (1993b).

More recently, close observers of the Fed have expressed similar concerns, citing the rapid growth in liquidity in 2003 and 2004 and the exceptionally low real interest rates since 2001 (Unsigned (2005a,b)). Our estimates are consistent with these sentiments that the Fed responded only weakly to inflation in those periods. Our estimates indicate that monetary policy regime was active during 2006:3-2007:4. Prior to 2006:3, interest rate had increased and was kept high until 2007:3. At 2006 August meeting, Governor Lacker expressed that some inflation risks remained and even preferred an increase of the federal funds rate target, and also at 2007 August meeting, the Committee's predominant policy concern continued to be the risk that inflation might fail to moderate as expected. For moderately elevated inflation, the FOMC had kept relatively high FFR target during this period with concerns related to potential inflation pressure.[18] After the recent financial crisis, monetary policy has become passive, and the target for FFR had been set at between 0 and 1/4 percent by the end of our sample period.

Figure 5 presents the extracted fiscal policy regime factor and estimated threshold. Fiscal policy regime is active when the level of FP factor is below the threshold. Estimated state distribution shows that fiscal policy regime had been more unstable during our sample period than monetary policy regime shown earlier in Figure 3. Figure 6 plots historical data on the fiscal variables we consider and the estimated active fiscal policy regimes which are marked as shaded areas. We find that the estimated state distribution from our endogenously switching fiscal policy rule accords

[17]Romer and Romer (2002) also consider this point and quotes Chairman William McChesney Martin's congressional testimony related to the 1955 inflation.

[18]See FOMC statements released on August 8, 2006 and August 7, 2007.

well with narrative accounts of the important historical episodes. Fiscal policy was active at the beginning of our sample period. Despite the extremely high level of debt from World War II expenditures, Congress overrode President Truman's veto in early 1948 and cut taxes. From 1950-1953, policy became passive, as taxes were increased and taxes on excess profits were extended into 1953 to finance Korean War. During the 1960s, fiscal policy became passive again with decreasing debt to GDP ratio. The 1974-1986 period contains at least three episodes of discretionary active tax policy: 1975 fiscal expansion initiated by President Ford's tax cut following the oil price shock, the military build-up started by President Carter and strengthened during Reagan's presidency, and 1982 tax cut by President Reagan (Favero and Monacelli (2005)). During this period, our estimates capture these episodes as active fiscal regimes.

During the 1980s, with Reagan Administration's Economic Recovery Plan of 1981, fiscal policy was active. Following President Clinton's tax hike in 1993, however, fiscal policy switched to being passive. Subsequent tax reductions in 2002 and 2003 President Bush made fiscal policy active again.[19] In 2008, Congress passed the Economic Stimulus Act to boost the economy from the recession after 2007-2008 financial crisis and fiscal policy regime has been kept active.

3 Policy Interactions via Extracted Policy Regime Factors

3.1 A New Approach to Policy Interactions

There are two distinct regimes that permit monetary and fiscal policies to accomplish their two primary tasks of price level determination and debt stabilization (Sargent and Wallace (1981), Wallace (1981), Aiyagari and Gertler (1985), Sims (1988) and Leeper (1991)). While economic theory emphasizes how policies in a particular monetary and fiscal regime must interact to determine the price level uniquely, previous empirical studies in monetary and fiscal policy interactions tend to focus on dynamic patterns of correlation among policy variables (King and Plosser (1985), Melitz (1997, 2000), von Jagen et al. (2001), Muscatelli et al. (2002) and Kliem et al. (2015)).

Some recent works explore dynamic interactions between monetary and fiscal *policy rules* via exogenous regime switching models, rather than *policy variables* (Favero and Monacelli (2005), Davig and Leeper (2006b), Gonzalez-Astudillo (2013) and Bianchi and Ilut (2014)). This line of exploration gives an interpretation based on policy regime interactions which is consistent with what economic theory emphasizes. However, most literature treats policy regime changes as exogenous,

[19] As argued in Davig and Leeper (2006b), since recessions automatically lower revenues and raise debt, a negative correlation between taxes and debt may naturally observable. And the negative response of taxes to debt in the active fiscal regime might be regarded as a consequence of business cycles. Two active fiscal regimes, the late 1940s and 1953:4-1955:1, almost exactly coincide with the cycle. But there are extended periods of active behavior, which include but do not coincide with recessions (2008:1-2009:2). There are also instances in which recessions occur during periods of passive fiscal policy (1990:3-1991:1 and 2001:1-2001:4). Taken together these results suggest that the fiscal policy does more than simply identify active regimes with economic downturns. More interestingly, during recession periods, there is a tendency that the extracted fiscal policy factor decreases. It is, in other words, the probability to be passive in the next period decreases.

evolving independently of the state of the economy, and it is difficult to rationalize an exogenous policy change as an actual purposeful policy behavior and a systematic response to changes in the macroeconomic environment.

Under these limitations of previous empirical studies on policy interactions, we aim to explore a new empirical approach. We consider endogenous regime switching monetary and fiscal policy rules to describe purposeful policy behaviors where policy coefficients systematically respond to the state of the economy. And we examine policy regime interactions using policy regime factors which determine policy regimes explicitly in our policy rules.

As we discussed earlier, we interpret latent policy regime factors as an internal information set of policy authorities, and each policy authority independently determines her policy rule based on her internal information. Estimated policy regime factors therefore can be used in policy analyses as proxies of internal information of policy authorities. In other words, we can interpret it as an inferred policy factor representing observable part of internal information of policy authorities.

Using extracted policy regime factors from monetary and fiscal policy rules, we can investigate not only regime changes in each policy rule but also systematic interactions between the two policy rules. Endogenous evolution of regime is an essential elements in this analysis because it points research toward understanding how monetary policy's choice of its rule may influence fiscal policy's choice of its rule (and vice versa). As an example, consider a conduct of monetary policy. Monetary policy decisions are based on the review of economic and financial developments. In reviewing the economic outlook, the FOMC considers effects of the current and projected paths for fiscal policy to key macroeconomic variables such as GDP, employment, inflation and others. In this way, fiscal policy has an indirect effect on the conduct of monetary policy through its influence on the state of the economy. More specifically, if the Recovery Act of 2009 is projected to stimulate economic growth, the central bank would assess how those programs would affect its key macroeconomic objectives and make appropriate adjustments to its monetary policy. In that sense, under the exogenous regime switching, we cannot sensibly analyze the dynamic interactions of policy regimes because policy regime evolves independently of endogenous economic variables.

In this section, we consider a bivariate time varying coefficient VAR models (TVC-VAR) with extracted policy factors to investigate the interactions between two policy authorities. Estimation errors in the extracted policy factors are ignored here but in our bootstrap analysis of factor augmented VAR in Section 5, they are fully taken into consideration.

3.2 Time Varying Coefficient VAR on Policy Regime Factors

Figure 7 presents the extracted policy regime factors from both monetary and fiscal policy rules. Since policy regime factors and thresholds determine policy regime changes in monetary and fiscal policy rules in our model, co-movement between two policy regime factors may provide useful information about the policy interactions. The correlation between two policy regime factors is 0.48. In our context, for example, if the monetary factor is more likely to be above the estimated threshold (active monetary policy) then the fiscal factor is also more likely to be above the estimated threshold (passive fiscal policy). The positive relationship between monetary and fiscal regime factors implies that there is a tendency for them to be active monetary/passive fiscal or passive monetary/active fiscal given the estimated thresholds.

As a preliminary analysis, we consider a time invariant VAR using policy regime factors. We consider the full sample period (1949:2-2014:2) and the subsample period (2000:1-2014:2), respectively. For the full sample period, average of monetary factor is 0.71 (active), and average of fiscal factor is -0.28 (passive). The sub-sample period, in contrast, average of monetary factor is -1.24 (passive) and average of fiscal factor is -3.79 (active) given estimated thresholds.[20] Further estimation results from time invariant VAR analysis are added in Appendix for a comparison.

Our preliminary analysis supports that policy interactions have changed historically. Also, it is natural that we assume time varying policy interactions based on previous empirical studies. TVC-VAR models have been considered in the analysis of macro economy by many different authors. Cogley and Sargent (2005) investigate unemployment and inflation dynamics to provide evidence about the evolution of measures of the persistence of inflation, prospective long-horizon forecasts of inflation and unemployment in TVC-VAR. This paper finds that long-run mean, persistence and variance of inflation has changed, and the Taylor principle was violated before Volcker period. Primiceri (2005) studies changes in monetary policy in the U.S. over the postwar period. This paper finds that there are the systematic responses of the interest to inflation and unemployment exhibit a trend toward a more aggressive behavior, and this has had a negligible effect on the rest of the economy. Gali and Gambetti (2009) investigate the causes of a reduction in volatility in the Great Moderation via TVC-VAR. All of them find fundamental changes in the U.S. economy over the last decades. To provide a more in-depth analysis of the policy interaction, we also consider TVC-VAR with policy regime factors from monetary and fiscal policy rules. In terms of methodology, we use the classical kernel methods as in Giraitis et al. (2014, 2015) instead of Bayesian approach.[21]

We consider a TVC-VAR model given by

$$y_t = \Psi_t y_{t-1} + \eta_t$$

where $y_t = (w_t^m, w_t^f)'$, Ψ_t is 2-by-2 matrix of coefficient processes, and $\eta_t = (\eta_t^m, \eta_t^f)'$ is the noise with $E\eta_t\eta_s' = 0, t \neq s$, $t = 1, 2, \ldots T$.[22] The TVC Ψ_t is estimated as

[20]The correlation between policy regime factors from monetary and fiscal policies during the sub-sample period is 0.77 which is greater than 0.48 in the full sample period. We compare the averaged interaction between monetary and fiscal regimes in the full sample and sub sample periods by considering the whole policy regime factors and the last part of policy regime factors, respectively. The subsample period includes the financial crisis and great recession.

[21]The usual advantages and disadvantages of the classical approach relative to the Bayesian approach are applicable for the comparison between our kernel method and the Bayesian VAR methodology. The kernel method is used here, since we follow the classical approach for all our empirical analysis in the paper.

[22]For the actual empirical analysis, we consider an extended TVC-VAR model including the intercept term and additional lags. The required extension is straightforward.

$$\widehat{\Psi}_t = \left(\sum_{s=1}^{T} k_{t,s} y_s y'_{s-1} \right) \left(\sum_{s=1}^{T} k_{t,s} y_{s-1} y'_{s-1} \right)^{-1}$$

with the weights $k_{t,s} = K((t-s)/H_\Psi)$ are given by the kernel function $K(x) \geq 0$, $x \in \mathbb{R}$, and the bandwidth parameter H_Ψ. We use the Gaussian kernel, and the bandwidth parameter is chosen by the standard leave-one-out cross-validation (Stone (1974)) procedure. More specifically, we select $\widehat{H}_\Psi$ minimizing

$$\sum_{t=1}^{T} \left\| y_t - \widehat{\Psi}_{-t} y_{t-1} \right\|^2$$

where $\widehat{\Psi}_{-t}$ is an estimate of Ψ_t obtained by removing the observation pair (y_t, y_{t-1}) for each t, and $\| \cdot \|$ denotes the standard Euclidean norm.

There is an important econometric issue in the estimation of TVC-VAR. As is well known, equations in a VAR with time-invariant coefficients may be estimated either individually as a univariate regression or systematically as a multivariate regression. The two approaches yield identical estimates. This is no longer applicable for a TVC-VAR model. The estimate of TVC is critically dependent upon the choice of kernel function, and in particular, bandwidth parameter. We estimate our TVC-VAR model using a system approach, which implies that we use the same kernel function with the same bandwidth parameter for all equations. Therefore, we effectively put restrictions on the choice of kernel and bandwidth across equations. It turns out that these are important restrictions. In fact, for individual univariate regressions, the cross-validation method picks too small bandwidth generating explosive dynamics. We believe that the system estimation extracts the common movement in a low frequency (with larger bandwidth) we want to analyze in the paper while the equation by equation estimation captures relatively high frequency dynamics (with small bandwidth).

Our estimation results are obtained from TVC-VAR(2). Given the coefficients allowed to vary nonparametrically over time, we think the second-order VAR is flexible enough to capture the dynamic interactions of the policy regime factors from our regime switching model.[23] For the identification of the TVC-VAR, we employ a triangular scheme to orthogonalize the innovations, where we assume fiscal factor is contemporaneously affected by monetary factor but not vice-versa. This scheme implies that monetary authority changes their policy stance first, and fiscal authority subsequently makes their policy decision after they observe the monetary policy changes. We also consider the identification scheme based on the reverse ordering where monetary factor is contemporaneously affected by fiscal factor but not in opposite direction. This produces the IRFs

[23]TCV-VAR(1) yields some awkward dynamics. All our results continue to hold in high-order VARs at least qualitatively, though the variability of estimates increases as we include more lags. Therefore, we choose TVC-VAR(2) for parsimony in our specification.

with similar dynamic patterns, and thus we do not report results from using this identification scheme.

In our TVC-VAR model, traditional impulse response functions are no longer an appropriate measure of responses because of time variation in the coefficients Ψ_t. To properly take into account such time varying coefficients, we use the conditional impulse response functions suggested in Gambetti (2006) which determines the effects of a shock by the future time-varying coefficients, thereby rendering them dependent upon the time when the shock is given.[24] For each quarter, we draw IRFs for horizons up to 20 quarters. In all 3-dimensional IRFs we report, quarters after the shock are on the x-axis, the time periods from 1949:2 to 2014:2 on the y-axis, and the values of the response on the z-axis. To focus on the time varying nature of IRF dynamics, we plot the IRFs starting from the estimated threshold levels for each quarter and check the sign and magnitude of the responses for a convenient description of the direction and magnitude of responses.

Figures 8-9 present the responses of the policy regime factors to a negative one standard deviation shock to the monetary factor in our TVC-VAR. The transparent blue surface in each figure represents the estimated threshold for each policy rule. Figure 8 shows that monetary policy rule becomes passive after the negative shock to monetary policy regime (monetary factor going under the threshold surface), and it remains passive for the next 20 quarters during most of the time periods we consider. This implies a stability in monetary policy behavior, which is particularly strong over a sample that includes the 1980s. This seems consistent with the common belief that the Fed kept a strong and consistent policy objective to control inflation during this period. Figure 9 shows that fiscal policy becomes active after the negative shock on the monetary policy regime (monetary factor going under the threshold surface) during most of our sample period except in the 1950s and 1980s where the fiscal factor moves up and stays above the threshold surface after a few quarters from when the monetary regime shock occurs. During these periods, fiscal policy rule was active, for the wartime fiscal financing and military build-up, and the fiscal policy authority seems to act independently of monetary policy stance. Except during the 1950s and 1980s, that monetary regime shock drives fiscal policy toward an active to produce a passive monetary/active fiscal combination that delivers a determinate, well behaved equilibrium according to economic theory.

Figures 10-11 show the responses of policy regime factors to a negative one standard deviation shock to fiscal regime. Figure 10 shows that with the negative shock to fiscal regime, fiscal policy becomes active (fiscal factor going under the threshold surface) in most of the sample period, suggesting a persistent fiscal behavior. There are, however, three short periods in the 1950s, 1970s, 1980s where fiscal regime moves up above the surface and stays there for several quarters, implying that the fiscal policy becomes passive during these periods. On the other hand, Figure 11 shows the response of the monetary factor to the negative shock to fiscal regime and the subsequent switching to active fiscal policy regime. It is clearly shown that the monetary policy responds to the fiscal

[24] For all out of sample coefficients needed for the computation of the conditional IRFs, we use the values of the coefficients at the end of the sample.

policy shock, though the direction of the response is opposite before and after the 1980s. When fiscal policy regime becomes active, monetary policy also becomes active or responds insignificantly before the 1980s, while monetary policy becomes passive after the 1980s. Especially in the 1950s monetary policy tends to become active. When fiscal policy is active, more active monetary policy which responds strongly to inflation will be destabilizing since it amplifies the impacts of a fiscal policy shock to taxes. The doubly active policy mix, according to theory, stabilizes neither inflation nor debt.

We find that during the 1980s, policy interactions between monetary and fiscal authorities are relatively weak with a small magnitude of response. Kliem et al. (2015) argue that the low-frequency relationship between primary deficits over debt and inflation has become insignificant after 1980 as the Fed kept active regime independently after 1980. However, we observe a strong interaction between policy regime factors with a large magnitude of responses after the 1990s. This is in sharp contrast to previous findings in the empirical policy interaction literature including Kliem et al. (2015).[25]

During the 1990s and 2000s, policy regimes were mostly active monetary/passive fiscal. Leeper (1991) shows that under this combination of policy regimes any fiscal disturbance has no real effect and leaves the present value of current and expected future primary surpluses unchanged, and hence the output growth, inflation and nominal interest rate. However, after a negative shock to the fiscal policy factor that makes the fiscal regime active, monetary policy tends to become passive. Our empirical finding supports a finding in Davig et al. (2004) and Davig and Leeper (2006b): the fiscal theory is operating whenever economic agents believe it is possible for fiscal policy to become active with on-going regime change, even when the rules in place at a given moment would suggest that Ricardian equivalence should hold if regime were fixed. A central bank that does not account for on-going regime change, therefore, would mistakenly interpret higher inflation as due to some other demand shocks other than fiscal policy.

Our estimation results indicate that the interaction between monetary and fiscal policies has become stronger in the recent sample period since 2008. We see clearly that fiscal policy tends to be more active when monetary policy becomes passive, and monetary policy seems to be more passive when fiscal policy becomes active during this period. Since the financial crisis and great recession, the monetary and fiscal policy interactions seem apparent as can be inferred from the recent expansions of central bank balance sheets with several rounds of quantitative easing (QE) and surging levels of sovereign debt, as well as the ensuing fiscal stress facing major advanced economies.

Finally, we consider impulse response functions on selected years and impulse response horizons to better understand how they evolve over horizons on selected time periods, and also over time at selected horizons. Figure 12 shows the impulse responses of policy regime factors to a negative one

[25] We exclude the period after 2008 and re-estimate our TVC-VAR to check whether policy interactions during the 1990s and 2000s may be misled by a strong policy interaction after 2008 in our estimation. However, we still find similar interactions between monetary and fiscal policies, for the sub-sample period (1949:2-2007:4).

standard deviation shock to monetary policy regime on selected years. The first column represents the impulse responses of monetary factor to monetary regime shock given on the first quarters of 1965, 1982, 2008, 2013. For 1982 and 2013, effects of monetary regime shock live longer than other selected years. The second column represents the impulse responses of fiscal factor to monetary regime shock on the same selected years. Overall, when the monetary policy regime becomes passive, the fiscal policy regime tends to become more active but the magnitude and persistency of the responses vary across different time periods. In terms of the magnitude of the response, fiscal policy responds weakly to the monetary policy shock in 1982 compared to other selected years we consider. In 2013, however, the fiscal policy regime becomes passive with a large magnitude of response and the persistency of shock effect.

Figure 13 shows the impulse responses of policy regime factor to a negative one standard deviation shock to the fiscal regime on selected years. The first column represents the impulse responses of fiscal factor to the shock to fiscal regime given on the first quarters of 1955, 1982, 2008, 2013. For 2008 and 2013, effects of fiscal regime shock live longer than other selected years. The second column represents the impulse responses of monetary factor to the shock to fiscal regime. Overall, from the early 1980s, monetary policy regime becomes passive when fiscal policy regime becomes active, and the magnitudes of responses increase further during 1990s and 2000s. Before the 1980s, during most periods, fiscal policy regime also becomes passive even if monetary policy regime becomes passive. In 1982, fiscal policy becomes active as monetary policy becomes passive, but the magnitude of response is smaller than those from the 1990s and later. In 2008 and 2013, monetary policy regime becomes passive with a large magnitude and the persistency of the shock effect.

Figure 14 presents how effects of policy regime shock evolve over time at the two selected horizons, 5 and 15 quarters after the initial shock. The four columns show from left to right the impulse responses of monetary policy regime to monetary regime shock, of monetary policy regime to fiscal regime shock, of fiscal policy regime to fiscal regime shock and of monetary policy regime to fiscal regime shock. The top panels show the impulse responses at 5 quarters ahead from the initial shock given at each year in our sample period, while the bottom panels show the responses at 15 quarters after the initial shocks. The second column clearly shows that fiscal policy regime becomes active after the 1990s when the monetary policy regime becomes passive, and the magnitude of responses has increased. As discussed before, the fourth column shows that the monetary policy responds to the fiscal policy regime shock differently before and after the 1980s.

In this section, we have demonstrated how we may use the policy regime factors extracted from our endogenous regime switching policy rules to investigate the dynamic interaction between monetary and fiscal policy rules using a TVC-VAR model. We find that the patterns of monetary and fiscal policy interactions have changed during the past six decades and that the degree of interactions between two policy authorities has become stronger in the recent years.

4 Macro Economy and Policy Regime Factors

In this section, we study which macro variables explain the regime changes in the policy rules and how the policy factors are related to macro variables. Changes in policy regime factors may influence the macro economy in two ways. First, changes in policy regimes influence the economy directly via changes in interest rate and tax. Second, changes in policy regime factor influence the economy through the economic agents' beliefs or expectations about current and future policy regimes. Policy regime factors are related to policy disturbances which are policy changes not driven by inflation rate for monetary policy and by debt level and government spending for fiscal policy, so reflect other systematic but not explicitly modeled aspects of actual policy behaviors. To private agents, policy disturbances signal possible policy regime changes in future by altering instruments more or less aggressively than the usual policy variables imply.

Since the latent policy regime factors are not observable, economic agents also estimate the latent policy regime factors to make an inference about current and future policy regimes as econometrician did. Economic agents make an inference about underlying policy regimes via policy regime factors. Then the estimated policy regime factors can be interpreted as the quantified agents' beliefs on the status of policy authorities. When there is a change in the inferred policy regime factors, it will affect the transition probability of policy regime change. If the agents are rational, they will re-optimize their lifetime utility after consideration of this effect. Through this channel, changes in policy regime factors have effects on various macro variables.

We search macroeconomic variables, which effectively explain the dynamics of policy regime factors, among a very large set of variables. To effectively handle the high dimensional issues, we use the adaptive least absolute shrinkage and selection operator (adaptive LASSO) in Section 4.1. We also analyze effects of changes in policy regime factors to some key macroeconomic variables by using factor augmented VAR (FAVAR) in Section 4.2 and the responses of policy regime factors to shocks from macro variables using VAR with six selected variables in Section 4.3. By investigating the interactions among policy regime factors with macro variables, we may provide meaningful implications for the construction of dynamic stochastic general equilibrium (DSGE) models relevant for policy interactions and macroeconomics.

4.1 Identifying Macroeconomic Factors for Policy Regime Factors

We first aim to pin down the variables which explain the policy regime factors determining the regime switchings in the monetary and fiscal policy rules. Since the policy regime factors are interpreted as the observed part of the internal information set of the respective policy makers, it is sensible to search for those variables among the commonly considered macroeconomic and financial variables. We consider the quarterly macro time series used in Koop and Korobilis (2009, KK hereafter) which are similar but not identical to the monthly variables considered in Bernanke et al. (2005, BBE hereafter) and Stock and Watson (2002, 2005, SW hereafter). We investigate policy interactions at a lower frequency using quarterly data set, and for this we update the 113 quarterly time series used in KK, which spans from 1959:1 to 2006:3. Most of the series considered in KK are similar to those in BBE only with minor differences. The same overall categories are used in both data sets, but KK add some new series such as saving and investment while they drop some particular items in production.

We add to KK data set seven variables on personal consumption expenditures and stock prices that are considered in BBE but not included in KK data set. They include four personal consumption expenditure series (total, services, nondurables, and durables) and three stock price indexes (Dow Jones Stock Average-30 Individual Stocks, S&P Stock Price index-400 Industrials, S&P Stock Price Index-Composite Common Stocks). In addition, we add output gap series, two extracted policy factors and six more fiscal variables to better understand whether and how monetary and fiscal regime factors are explained by macro and fiscal variables. Six fiscal ratios include net interest payment to government expenditure ratio, net interest payment to debt ratio, debt to GDP ratio, government spending to GDP ratio, military spending to GDP ratio, and tax revenue to GDP ratio. Short-term interest rate and tax revenue to GDP ratio are not considered in our analysis of monetary and fiscal policy rules, respectively, for finding the macro-finance factors that have explanatory power for monetary and fiscal regime factors.

To effectively select a set of such macro-finance factors determining each of the inferred information indexes of policy authorities, we consider the aforementioned 129 variables as potential candidates and employ the adaptive LASSO (Least Absolute Shrinkage and Selection Operator) method, a popular shrinkage regression method known to perform very well.[26] Basically, this method adds a penalty for model complexity (L_1-regularization) to ordinary least squares regression, yielding solutions which are sparse in terms of the regression coefficients. To be specific, let y denote either monetary regime factor or fiscal regime factor and X the set of potential candidate variables. Then the adaptive LASSO estimator is given as[27]

$$\hat{\beta}_L = \underset{\beta}{\operatorname{argmin}}\ (y - X\beta)'(y - X\beta) + \lambda \sum_{i=1}^{N} \frac{|\beta_i|}{|\hat{\beta}_i|},$$

where λ is a nonnegative regularization parameter, N the dimension of X, and $|\hat{\beta}_i|$ is the adaptive weight based on the OLS or ridge regression estimator $\hat{\beta}_i$, which is consistent for the true coefficient β_i. The weights are therefore bigger when the true coefficients are large, thereby giving smaller penalties when the associated variables contribute significantly to explaining y.

We choose the regularization parameter λ which minimizes the Bayesian Information Criterion (BIC)[28] given by $BIC(\lambda) = \| y - X\beta(\lambda) \|^2 + \log(n)\sigma_\epsilon^2 df(\lambda)$, where n is the number of observations,

[26] Zou (2006) introduces the adaptive LASSO and shows that it has the oracle property, which in particular implies that we may treat the regression with the selected regressors as if it were the true regression model.

[27] y is the demeaned series and X is the set of standardized series. Also, we transform X properly to ensure stationarity. Required transformation is done using the code based on KK and described in Appendix.

[28] Since our goal is to pin down only those essential variables, we use BIC which is known to choose a more

$df(\lambda)$ the degree of freedom given by the number of non-zero coefficients, and σ_ϵ^2 represents the residual variance of a low-bias model defined as $\sigma_\epsilon^2 = \frac{1}{n}\|y - X^*y\|^2$, with X^* being the Moore-Penrose pseudo-inverse of X. Therefore, we select λ which gives a balance between the goodness of fit and the complexity of the model. It is well known that the solution to adaptive LASSO objective function is nonlinear and no closed form solution exists. It is also known that the adaptive LASSO estimates of the set of the selected variables X^*, their coefficients $\hat{\beta}_L$ and the associated regularization parameter λ can be obtained in the least-angle regression algorithm suggested in Efron et al. (2004) and Rosset and Zhu (2007). The number of the selected variables for policy regime factors are 29 and 12, respectively.

Table 4 reports the 12 variables with larger coefficients from the selected model for the MP regime factor, their estimated coefficients and standard errors.[29] Tax revenue to GDP ratio is selected as one of most important macro variables which may explain the level of monetary regime factor. Note that net interest payment to government expenditures ratio is also related to fiscal policy stance since the interest payment burden can be a strong incentive to change the tax policy rules. There is a tendency that periods of increasing net interest payment to government expenditures ratio are matched with dates of significant legislation to increase taxes. Also, the variables which are commonly considered in the estimation of monetary policy rule are selected with relatively large coefficient estimates. They include producer price index, personal consumption expenditure (PCE) price index, and variables related with employments such as all employees and average weekly hours. Some variables related with the expectation of future economic status are also selected, and they include University of Michigan index of consumer expectation and NAPM (National Association of Purchasing Managers) new orders index, vendor deliveries index and housing starts.

Similarly, Table 5 presents 12 variables of the selected model for the fiscal regime factor, their estimated coefficients, and standard errors. Net interest payment to debt ratio is selected as one of most important variables to explain fiscal regime factor. Under high and rising debt, an increase in interest rate may push up interest costs on the debt sharply. A higher interest payments on the debt tends be followed by a change in fiscal policy stance to keep a sustainable fiscal policy in the long run. Extracted monetary policy factor, M1 money stock and the spread between Moody's Baa bond yield and the federal fund rate are also selected as important variables to explain the fiscal regime factor. Similarly to monetary regime factor, all employees, average hourly earnings, housing starts are chosen with relatively larger estimates.

There are some variables which are commonly selected in both policy regime factors including net interest payment ratio, housing starts, all employees. More important finding from the adaptive LASSO analysis is that the fiscal variables, tax to GDP ratio, net interest payment to government

parsimonious model than other selection criteria such as Akaike's information criterion and Mallow's C_p that are also commonly used for selection of the regularization parameter λ.

[29] Due to the oracle property of the adaptive LASSO estimators, the regression of MP regime factor on the selected regressors can be viewed as the true regression for which the OLS estimators are optimal. We therefore use the OLS estimates and their standard errors.

expenditures ratio are selected to be most important variables explaining the monetary regime factor, and the net interest payment to debt ratio is chosen to be significant for the fiscal regime factor with a larger estimated coefficient. This result can be regarded as an indirect evidence of policy interactions.

We note that the shrinkage regression analysis we use to select the variables explaining monetary and fiscal regime factors is static and based only on the contemporaneous relationship between the levels of policy regime factors and the variables reflecting the macroeconomic environment. In what follows, we study their dynamic interactions in a factor augmented VAR model.

4.2 Dynamic Interaction between Regime Factors and Key Macro Variables

In this section, we examine how the policy regime factors interact with key macroeconomic variables using Factor Augmented VAR (FAVAR) introduced in Bernanke et al. (2005). We continue to consider the same set of variables used in our adaptive LASSO estimation above, but with a different objective. While we try to learn which variables are linked to the policy regime factors in the adaptive LASSO analysis, we now investigate how the changes in the policy regime factors affect key macroeconomic variables such as inflation, GDP, unemployment and others. In our endogenous regime switching model, policy regime factors systematically respond to policy shocks due to the endogeneity between policy shocks and innovations of policy regime factors. The values of the policy regime factors in the next period move up or down depending on the realized policy shock in the current period, and policy rules switch correspondingly either from passive to active or from active to passive. Such systematic changes in policy rules will certainly influence the macroeconomy. For example, when monetary policy regime switches from passive to active, interest rate increases and consequently inflation rate and consumption will decrease. Of course, the change in the policy regime factor may not be big enough to cause policy rule to change, but it may still influence macroeconomy through the expectation effect that we discussed earlier.

As in BBE, we assume that the time series X_t containing all 127 macro variables we consider here are related to the policy regime factors as well as the leading components of X_t, viz.,

$$X_t = \Lambda C_t + e_t = \Lambda^f F_t + \Lambda^w W_t + e_t \tag{7}$$

where W_t represents the MP and FP policy regime factors, F_t the principal components of X_t net of the effect from W_t,[30] and e_t an error term. The economy is therefore assumed to be affected by both F_t and W_t via their influence on all of the macro and financial variables included in X_t. We may interpret the leading factor F_t as an information index extracting additional information on general macroeconomic environment from the variables contained in X_t beyond the information already captured by our policy regime factors, which we interpret as the inferred internal information index of policy authorities. The joint dynamics of $C_t = (F_t, W_t)$ are assumed to follow a finite order

[30] To obtain the principal components F_t orthogonal to W_t, we first obtain the principal components F_t^o from X_t, and fit X_t by the OLS regression as $X_t = \hat{\Lambda}_o^f F_t^o + \hat{\Lambda}_o^w W_t$. Then obtain F_t as the principal components of $X_t - \hat{\Lambda}_0^w W_t$.

invertible VAR process as $\Phi(L)C_t = v_t$, which can be written as an infinite order VMA process as $C_t = \Phi(L)^{-1}v_t$, where v_t is a white noise process. Then we have $X_t = \Lambda\Phi(L)^{-1}v_t + e_t$, where $\Lambda\Phi(L)^{-1}$ contains the impulse responses of each variable in X_t to shocks in the common components F_t and W_t. We assume that the common components F_t and W_t jointly capture most of systematic movements in X_t, and the error process e_t can be viewed as idiosyncratic measurement errors.

We compute impulse response functions for each variable in X_t to a shock in the policy regime factors W_t and their confidence intervals via bootstrapping, following the two-step principal component approach used in Bernanke et al. (2005), to which the readers are referred for details on the implementation the two-step approach for FAVAR models. The two-step approach implies the presence of generated regressors in the second step. According to Bai (2003), the uncertainty in factor estimation is negligible when the number N of variables included in X_t is large relative to the sample size T,[31] which does not hold in our case with $N = 127$ and $T = 261$. The confidence intervals on the impulse response functions we report below are based on a bootstrap procedure suggested in Kilian (1998) that accounts for the uncertainty in the factor estimation.[32]

To implement FAVAR in our context, we use first five leading principal components from 129 macroeconomic variables, monetary regime factor and fiscal regime factor.[33] For the structural identification, we assume that monetary regime factor and fiscal regime factor are contemporaneously affected by five principal components. For the ordering of monetary and fiscal regime factors, we consider two possible cases as in the TVC-VAR analysis. We consider various lags of FAVARs (5,8 and 12 lags) but employing 5 lags gives very similar results as found with the greater number of lags. Here we report the results from the fifth order FAVAR. Our main results are shown in Figures 15-18. Each figure represents impulse responses with 90% confidence intervals of policy regime factors and some key macroeconomic variables to the change in policy regime factors.[34] Figure 15 shows that monetary regime factor increases with a positive one standard deviation shock, i.e., the probability to be active monetary policy regime increases. The level of monetary regime factor is around the threshold after 9 quarters. Consequently, fiscal regime factor also increases and the probability to be passive fiscal policy regime increases with some lags.[35]

As shown in Figure 16, effects of monetary regime shock decreases GDP and increases unemployment rate with wide error bands including the base line. The price level decreases with some lags.[36] We observe a decrease in total loans from commercial banks also. As the probability of being more passive fiscal policy regime increases, debt to GDP ratio decreases. Net interest payment

[31] Specifically, $\sqrt{T}/N \rightarrow 0$ is required to hold as $N, T \rightarrow \infty$.

[32] Bernanke et al. (2005) also suggest the one-step method using Bayesian likelihood methods and Gibbs sampling to estimate the factors and the FAVAR simultaneously.

[33] We check the percentage of total variance explained by each component from principal component analysis. First two leading components and five components explain 41.3 % and 61.3 % of total variance respectively.

[34] The bootstrapped impulse responses involve 10,000 iterations.

[35] Note that this result is the averaged one from the changes in policy regime factors to macroeconomic variables during the full sample period.

[36] We report the impulse response of producer price index: all commodities. We check the impulse response of other measures of the price level (consumer price index with various subsections) and the responses are the same.

to government outlays ratio increases initially and then starts to decrease as the mixed effects from debt to GDP ratio and interest rate. With the monetary regime shock, long-term interest rate (10 year T-bill rate) increases initially but decreases after 14 quarters. Short-term interest rate (3 month T-bill rate) also responds the similarly as long-term interest rate. However, the monetary regime shock lives much longer in long-term interest rate than in short-term interest rate, which may be explained by a prolonged effect of monetary policy regime change. As monetary policy becomes active and fiscal policy becomes passive, new housing constructions decrease through two possible channels. First, a rise in interest rates would increase the cost of housing capital. This increased cost would reduce demand for housing services, and put downward pressure on the price of housing units. The depression of real housing prices would impede new investment in housing and the volume of new housing start would fall. Second, with an increase in taxes, say a personal income tax and a corporate profit tax, disposable income decreases and investment and employment also decrease, which reduces aggregate demand and subsequently volume of new housing start.[37]

Figure 17 shows that impulse responses to a positive one standard deviation shock to fiscal regime factor. Fiscal policy regime becomes more passive in terms of probabilities, and monetary policy becomes more active. Figure 18 shows that unlike to the shock to monetary regime, monetary policy regime becomes more active immediately after the fiscal policy regime is being more passive. Consequently, GDP decreases and unemployment increases. Inflation rate decreases consistently during 20 quarters. When we plot the impulse response of consumer price index for all commodities as the response of price level, the price level increases during 8 quarters after a shock and then decreases. Debt to GDP ratio and net interest payment to government outlays ratio have similar patterns with the previous case. Long-term interest rate starts from a negative value and increases gradually and then decreases. Total loans and housing starts also decrease.

Tables 6 and 7 report the variance decomposition results for the same macroeconomic variables considered in the previous Figures.[38] The columns report the contribution of changes in monetary and fiscal regime factors to the variance of the forecast of the common component, at the 16 quarter horizons.[39] The contribution of the shock to monetary regime factor has a huge effect to all variables we considered in previous Figures, especially to debt to GDP ratio and net interest payment to government outlays ratio. Not only for fiscal variables, but there is also a non-trivial effect to fiscal regime factor. Also, monetary policy regime shock explains 5%, 10% and 12% of GDP, unemployment and producer price index respectively. 19% and 8% of the error in the forecast of long-term interest rate and new housing starts are attributed to the monetary regime shock. The contribution of the shock to fiscal regime has similar effects to GDP, unemployment, producer price

[37]There may be many other plausible explanations for interactions between housing starts and monetary and fiscal policy regimes. Clearly, the housing market is one of important transmission channels which links the macro economy and policy regime effects.

[38]The Cholesky ordering for the Table 5 is 5 principal components-monetary regime factor-fiscal regime factor and for the Table 6 is 5 principal component-fiscal regime factor-monetary regime factor.

[39]We follow the variance decomposition suggested by Bernanke et al. (2005) in FAVAR context. The relative importance of a structural shock is assessed relative only to the portion of the variable explained by the common factors. See Bernanke et al. (2005) for details.

index and total loans with those of the monetary regime shock. The effect of the fiscal policy regime shock is nontrivial to explain the error in the forecast of all variables we considered and its effect is slowly spread to most variables.

We further consider the alternative scenario where fiscal policy authority does not respond to the change in monetary policy regime or does respond in the opposite direction to the original impulse responses to keep her own policy stance. We consider the series of unanticipated and moderate fiscal policy regime shocks which interrupt the fiscal policy to respond or induces it to respond in the opposite way to the given positive monetary policy regime shock. In Figures 19 and 20, we plot the original impulse response functions to the monetary policy regime shock in solid line and counterfactual response functions in black and red dashed lines respectively. When the fiscal policy strongly holds on to its own policy stance and does not respond to the change in monetary policy regime, the probability of the monetary policy staying in active regime in the next period will decrease. The impulse responses of price level lie above the original responses with such fiscal policy response. GDP decreases but less than the original response and the impulse responses of unemployment in alternative scenarios lie below the original response. In particular, when the fiscal policy responds in opposite way to becoming more active along with the more active monetary policy, GDP decreases initially and then increases. The unemployment decreases drastically, and the price level decreases much less than the original response. Even if the monetary authority intends to change the policy regime more actively to control high inflation, the effect of the monetary policy regime change seems to vary depending on the fiscal authority's reaction.

Similarly, in Figures 21 and 22, we consider the scenario where the monetary policy authority does not respond to the change in fiscal policy regime or does respond in opposite direction to the original impulse responses. Again, the price level decreases but much less than the original response. The responses of GDP and unemployment are changed slightly.

4.3 Macroeconomic Shocks on Policy Factors via SVAR

We scrutinized the effects of policy regime shocks to various macro variables using FAVAR in the previous section. In this section, we consider a small structural model to investigate the effects of non-policy regime shocks to policy regimes and their interactions.[40] Specifically, the structural form considered in this section is

$$\sum_{s=0}^{p} A_s y_{t-s} = \epsilon_t$$

where y_t is an m by 1 vector of time series and ϵ_t is a vector of i.i.d structural disturbances that are exogenous to the model. Those disturbances hit both non-policy and policy sectors of the economy,

[40] As we emphasized in previous adaptive LASSO and FAVAR analyses, actual monetary and fiscal policy behaviors are based on a high-dimensional vector of variables. Here, however, to focus on the effects of non-policy regime shocks to policy regimes, we simply select several variables based on the finding from previous analyses.

so

$$\epsilon_t = \begin{bmatrix} \epsilon_{Nt} \\ \epsilon_{Pt} \end{bmatrix}$$

where ϵ_{Nt} is the vector of non-policy disturbances. We estimate an identified VAR including four non-policy variables (output gap, consumer price index, 10 year T-bill rate and commodity price index) and two policy variables (monetary and fiscal regime factors). Two goods market variables-the output gap (Y), and consumer prices (CPI)-represent the real activity and price level. We consider the long term interest rate, the 10 year T-bill rate, as a financial variable. Commodity price index (CP) represents an "information variable" that is available at high frequencies and reacts instantaneously to shocks from other sectors of the economy. As policy variables, we add monetary and fiscal regime factors.

The identification treats the output gap and the price level as predetermined for the rest of the system, reflecting the view that producing, pricing decisions do not respond immediately to shocks from other sectors. The financial and information variables respond to goods market variables contemporaneously. We specify that policy authorities set their policy stances based on the information from goods market variables, long term interest rate and commodity prices within the quarter. The data used in this section is from previous analyses. All data are the first difference of logarithmic except the output gap, long term interest rate, and policy regime factors. We estimate with 5 lags.[41]

Figure 23 reports responses to all six exogenous disturbances. The first column shows the responses of six variables to one standard deviation shock to the output gap. The positive shock to the output gap generates an inflationary gap and indicates the growth of aggregate demand is outpacing the potential GDP with the full employment. A positive output gap possibly creates inflation as shown in the second row. With the positive shock to the output gap, the inflation rate increases and the long term interest rate also increases as a compensation of the inflation risk. The commodity price index increases and then decreases sharply. With the inflationary gap, the monetary policy regime becomes active. Under the output gap shock, the fiscal policy regime becomes passive and increases the tax by responding to the debt level strongly and to the government spending weakly. Shocks to real activities generate the clear policy interaction which is consistent with our empirical finding. In the second column, by a positive shock to the price level, the inflation increases and the long term interest rate increases as a compensation of an inflation risk. The higher price level reduces a consumer purchasing power, causing aggregate demand to fall. The commodity price index increases and decreases quickly. With the higher price level, monetary and fiscal regimes become active and passive respectively. The third column shows that when the long term interest rate increases, the price level and the commodity price index increase but the effects disappear quickly. With the increased price level, monetary policy regime becomes

[41] Adding more lags gives the similar results with more fluctuations in impulse responses.

active for a long time and fiscal policy regime becomes passive initially and turns to be active later. The output gap increases initially but becomes negative quickly with active MP and passive FP. In the fourth column, the commodity price index increases and goes back to initial level quickly. The monetary policy regime factor increases slightly by responding to the increased commodity price index. With the increased price level and decreases output gap, responses of monetary policy regime is unclear with the wider error band and the small magnitude of response. The Fiscal policy regime factor also increases as in the monetary policy regime factor and becomes negative after 10 quarters from the initial shock to the commodity price index. We observe here that impulse responses of two policy factors to a positive real activity shock are consistent with our previous findings from TVC-VAR analysis on the policy factors in terms of the sign and magnitude. The dynamics of policy regime factors from the other non-policy structural shocks may vary, but those non-policy shocks also generate the initial responses in the same direction to both policy factors.

The fifth and sixth columns represent the effects of policy shocks to other non-policy variables. When the monetary policy regime becomes active, the fiscal policy regime becomes passive and the output gap decreases initially. After few quarters, responses of the output gap become unclear with the wider error band. The price level decreases with some lags and the long term interest rate increases during first 6 quarters and then starts to decrease as the price level decreases. The commodity price index increases initially but becomes negative sharply. The last column shows that when the fiscal policy regime becomes passive, the output gap decreases and then the price level decreases. The long term interest rate increases initially and then decreases as the price level decreases. The commodity price index becomes negative sharply. The monetary policy regime becomes active only temporarily. Overall, impulse responses of macro variables to policy regime shocks are persistent with our previous findings in FAVAR analysis.

Table 8 presents the variance decomposition of forecast errors for each of the variables at the 16 quarter horizons. The forecast error decomposition is like a partial R^2 for the forecast error and the result from the variance decomposition suggests considerable interaction among the variables. We reaffirm that policy regime factors have nontrivial predictive power for key macro variables. More than 10% of the error in the forecast of the output gap is attributed to the fiscal policy regime shock. The shocks to the output gap, the commodity price index, the monetary and fiscal policy factors explain 10∼20% of the error in the forecast of the price level. The shock to the output gap and the price level explain more than 60 % of the variance of the error made in forecasting a long term interest rate. The shock to the long term interest rate and the monetary policy regime factor explain nontrivial fractions of the error in the forecast of the commodity price index.

We observe that only 55 % and 35 % of forecast errors of policy factors are attributed to own innovations respectively. Most of the error variances in the MP and FP regime factors are attributed to shocks other than own innovations, especially, the shock to the output gap explains more than 30% of the error in the forecast of both policy regime factors. The shocks to the long term interest rate, the commodity price index and fiscal policy factor are another important parts to explain the error made in forecasting the monetary policy factor. Similarly, the shocks to other macro variables and the monetary regime factor are important parts to explain the forecast error of the fiscal policy factor. Our result implies that policy regime factors are evolved endogenously by interacting with policy disturbances including policy and other structural shocks.

In our VAR analysis, the shock to the output gap contributes significant fractions of forecast errors of most variables. We also observe that the shock to the commodity price index explains more fractions of the error in the forecast of the policy regime factors than the shock to the price level explains. The commodity price index is commonly considered as an indicator of future inflation since it is quick to respond to economy-wide shocks to demand. Commodity prices generally are set in highly competitive auction markets and consequently tend to be more flexible than prices overall. As we consider the commodity price index as an information variable, the shock to the commodity price index may give more information about future inflation. In that sense, it is natural that policy regime factors are related to the commodity price index.[42]

5 Robustness Check

5.1 Robustness Check for Presence of Stochastic Volatility

All of our previous results are based on the endogenous regime switching model with a constant volatility. It has been emphasized by many authors, including Sims and Zha (2006), that the presence of time varying volatility or stochastic volatility may have serious deleterious effects on the empirical analysis of policy rules using U.S. macro time series.[43] In this section, we allow for the presence of general stochastic volatility in our model and consider a more general endogenous regime switching model to see how our previous results change.

To explain how we deal with the presence of a general form of stochastic volatility, we write our previous model extended to allow for the presence of stochastic volatility generically as

$$y_t = \alpha(s_t)x_t + \varepsilon_t \quad \text{with} \quad \varepsilon_t = \sigma_t u_t, \tag{8}$$

where $\alpha(s_t)$ is a state dependent regression coefficient, σ_t is a general time varying and stochastic volatility, and $u_t \sim iid\ N(0,1)$ independent of σ_t. Our approach to deal with the presence of stochastic volatility σ_t in the error term consists of two steps: estimation of σ_t in the first step ignoring the presence of stochastic volatility, and re-estimation of the model in the second step using the standardized regressand and regressors. Analogously with the feasible GLS correction for the usual OLS regression, our procedure relies on the feasible heteroskedasticity correction for the

[42]In the previous adaptive LASSO analysis, the commodity price index is selected but with a relatively small coefficient.

[43]However, the actual specification of time varying or stochastic volatility varies widely in their work.

presence of stochastic volatility in our MLE. Note that, if ε_t is observed, σ_t^2 can be estimated from

$$\varepsilon_t^2 = \sigma_t^2 u_t^2 = \sigma_t^2 + \sigma_t^2(u_t^2 - 1),$$

where $1 - u_t^2$ is i.i.d. with mean zero and independent of σ_t^2.

In the first step, we obtain the fitted residual under the constant volatility specification

$$\hat{\varepsilon}_t = y_t - \hat{\alpha}(s_t)x_t,$$

where $\hat{\alpha}(s_t)$ is the estimate based on our model with a constant volatility, and use $\hat{\varepsilon}_t^2$ to estimate σ_t^2 using the HP filter with an appropriately chosen smoothing parameter.[44] Subsequently, in the second step, we estimate the model

$$y_t^* = \alpha(s_t)x_t^* + u_t^*,$$

where y_t^* and x_t^* are volatility adjusted y_t and x_t, that is, they are given respectively by $y_t^* = y_t/\hat{\sigma}_t$ and $x_t^* = x_t/\hat{\sigma}_t$ with the estimate $\hat{\sigma}_t$ of σ_t obtained in the first step. Figure 24 presents estimated stochastic volatilities from monetary and fiscal policy rules.

To fully justify our procedure is difficult, and it certainly goes beyond the scope of this paper. We have two reasons why our procedure may not be entirely valid. First, for the validity of our procedure, we require that the fitted residual $\hat{\varepsilon}_t$ should consistently estimate the true residual ε_t even if we ignore the presence of stochastic volatility. Clearly, this is generally not warranted for nonlinear models estimated by the MLE as in our case. Second, volatility adjustment of y_t and x_t using the estimated $\hat{\sigma}_t$ may not behave well enough to give us what we wish to have. For instance, it may create nonnegligible cross correlation between x_t^* and u_t^*, in which case our procedure becomes totally invalid.

Nevertheless, if our procedure is valid, then we may expect that the new estimates are close to our previous estimates with smaller standard errors. Fortunately, this is exactly what we have and we may argue the validity of our procedure in this sense. We see this as a positive sign that our two step procedure to deal with the presence of stochastic volatility works properly at least for our model. The new results are presented in Table 9. As shown, there are only minor differences between the estimates from our original model and those from the model with stochastic volatility obtained using the two step procedure. In contrast, the standard errors of the estimates are substantially reduced as we expect. They are all reduced by more than 30%, with some of them

[44]If we let the smoothing parameter be λ and denote by $HP(\varepsilon_t^2)$ the HP filtered series of ε_t^2, then the smoothing parameter we use here is given by

$$\hat{\lambda} = \underset{\lambda}{\operatorname{argmin}} \sum_{t=1}^{T-1} \left| (\varepsilon_t^2 - HP_\lambda(\varepsilon_t^2))(\varepsilon_{t-1}^2 - HP_\lambda(\varepsilon_{t-1}^2)) \right|.$$

The reader is referred to Chang, Park and Yeo (2015) for a more detailed discussion of this approach to nonparametrically estimate the conditional mean of a given time series.

by as much as 50%.[45]

5.2 Robustness Check for Generated Regressor Uncertainty

The FAVAR analysis presented in Section 4 involves two different types of generated regressors, namely the principal components F_t and the estimated policy regime factors W_t. For our impulse response analysis in Section 4, we only consider sampling variations in principal components, regarding estimated policy factors as being given, in our bootstrap procedure. However, to fully account for uncertainties in our impulse response functions, it is necessary to introduce sampling variations in estimated policy factors as well as principal components. Needless to say, it is more desirable to bootstrap estimated policy factors jointly with principal components than bootstrapping each of them separately, to allow for their interactive dynamics. Below we explain in detail how this is done.

For our joint bootstrap procedure, we use the FAVAR structure in Section 4.2 as the data generating process consisting of observation equation (7), which relates the observed time series X_t to its principal components F_t and estimated policy factors W_t, and VAR(p) transition equation

$$\begin{pmatrix} F_t \\ W_t \end{pmatrix} = \Phi_1 \begin{pmatrix} F_{t-1} \\ W_{t-1} \end{pmatrix} + \ldots + \Phi_p \begin{pmatrix} F_{t-p} \\ W_{t-p} \end{pmatrix} + v_t,$$

where v_t an i.i.d. error term. Our joint bootstrapping scheme to account for sampling variations in both W_t and F_t is given in the following steps:

1. Estimate the observation equation $X_t = \Lambda^f F_t + \Lambda^w W_t + e_t$ to obtain parameter estimates $\hat{\Lambda} = (\hat{\Lambda}^f, \hat{\Lambda}^w)$ and residuals $(\hat{e}_t)$.

2. Generate bootstrap samples (e_t^*) by resampling from centered residuals $(\hat{e}_t - T^{-1}\sum_{t=1}^T \hat{e}_t)$ from Step 1 with replacement and obtain bootstrap samples X_t^* by $X_t^* = \hat{\Lambda}^f F_t + \hat{\Lambda}^w W_t + e_t^*$ using (e_t^*) and $\hat{\Lambda} = (\hat{\Lambda}^f, \hat{\Lambda}^w)$.

3. From (X_t^*), obtain bootstrap samples of principal components and policy factors (F_t^*, W_t^*) as follows:

   3-1. Pick out from (X_t^*) bootstrap samples of policy variables $(i_t^*, \pi_t^*, \tau_t^*, b_{t-1}^*, g_t^*)$ and use them to estimate policy regime switching models to obtain (W_t^*).
   3-2. Obtain principal components (F_t^{o*}) of X_t^*, and use (F_t^{o*}) and W_t^* from Step 3-1 to fit X_t^* by OLS in $X_t^* = \hat{\Lambda}_o^f F_t^{o*} + \hat{\Lambda}_o^w W_t^*$. Then define the principal components F_t^* orthogonal to W_t^* as the principal components of $(X_t^* - \hat{\Lambda}_o^w W_t^*)$.

[45] We also obtain $\hat{\sigma}_t$ using GARCH (1,1) or endogenous regime switching volatility model, and estimate the models with volatility adjusted y_t and x_t. Overall, the estimates are not sensitive to volatility model and estimation method used to deal with the presence of volatility.

4. Fit X_t^* by OLS using F_t^* and W_t^* in $X_t^* = \Lambda^{*f} F_t^* + \Lambda^{*w} W_t^*$ to obtain $\Lambda^* = (\Lambda^{*f}, \Lambda^{*w})$.

5. Fit VAR(p) on (F_t^*, W_t^*) to obtain $\Phi^* = (\Phi_1^*, \ldots, \Phi_p^*)$ and residuals (v_t^*).

6. Generate bootstrap samples (v_t^{**}) from centered residuals $(v_t^* - T^{-1} \sum_{t=1}^{T} v_t^*)$ from Step 5 with replacement, and use them together with Φ^* also from Step 5 to generate (F_t^{**}, W_t^{**}) recursively using VAR(p) transition equation.

7. Fit VAR(p) on (F_t^{**}, W_t^{**}) to obtain $\Phi^{**} = (\Phi_1^{**}, \ldots, \Phi_p^{**})$.

8. Obtain the double-bootstrapped IRF**'s using Λ^* and Φ^{**}.

9. Repeat Steps 6-8 B_v times.

10. Repeat Steps 2-8 B_e times.

11. Obtain confidence intervals for impulse response functions from the $B_e \times B_v$ number of double-bootstrapped impulse response functions IRF**.

Our bootstrap approach outlined above differs from the procedure used in Bernanke et al. (2005) only in that we have an additional step (Step 3-1) to properly account for sampling variations in estimated policy factors to compute the confidence intervals for IRFs. In total, we resample IRF's 100,000 times, with $B_e = 100$ and $B_v = 1,000$.

Figures 25 and 27 present IRFs in solid line and their 90% confidence intervals in dotted lines of policy factors to MP and FP regime shocks respectively. In both figures, red lines signify IRFs and their confidence intervals obtained earlier in Section 4 by considering sampling variations only in principal components F_t, while black lines represent those obtained by taking into account sampling variations in both F_t and estimated policy factors W_t, which is implemented in Step 3-1 in our bootstrap scheme above. Exactly as in Figures 25 and 27, Figures 26 and 28 present IRFs and their 90% confidence intervals of macro variables to MP and FP regime shocks respectively. In all figures, differences between red and black IRFs and confidence intervals reflect the newly introduced sampling variations in estimated policy regime factors. Here we observe that both confidence intervals are in most cases quite close to each other and, therefore the newly introduced sampling variations in estimated policy regime factors do not seem to affect the uncertainties in impulse response functions in any significant manner.[46]

5.3 Robustness Check for Presence of the Zero Lower Bound Period

Since December 2008, the FFR has been near zero and the central bank cannot stimulate the economy by lowering the interest rate further. During the ZLB period, the central banks rely on unconventional policy instruments such as "quantitative easing" and "forward guidance" to try to

[46] We shall also account for the uncertainties from estimated policy regime factors in the TVC-VAR analysis, and this will be reported in a future work.

affect long-term interest rates and influence the economy. The structural change in terms of the effectiveness of the FFR as a policy instrument raises questions on how we should sensibly deal with the data covering the ZLB period.

Two different approaches have been suggested to handle the issues related to the ZLB of interest rates. The first approach is to simply discard the ZLB period and use a truncated data series up to 2008:4, while the second approach is to handle the ZLB period using shadow rates such as those provided by Wu and Xia (2015) which may convey a further information about policy behaviors during the ZLB period. Since analyzing policy interactions after the financial crisis is one of our key interests, we take the second approach and use the estimated shadow rates from Wu and Xia (2015) to construct a new policy rate i_t^* by splicing together T-bill rate i_t until $t = 2008 : 4$ and the estimated shadow rate $\hat{i}_t$ from $t = 2009 : 1$.

Figure 29 compares the two monetary policy factors - the original factor we presented earlier which is extracted using the original T-bill rate i_t and the new factor extracted using the new policy rate i_t^*. Overall the regimes identified by the two factors are identical except for a short period in the early 1960s. This period is identified as a passive regime by the original factor, but contrastingly as an active regime by the new factor. The magnitudes of the factors are also similar overall, but the new factor tends to take larger values during troughs except during the most recent period since 2011:1 when it becomes smaller than the original factor. This means that the new monetary policy factor obtained from i_t^* sends a stronger signal that monetary policy will passive in the next period compared to what is predicted by the original factor. This may imply that the shadow rate embedded in the new policy rate i^* brings in more information relevant to the policy making such as that conveyed in the forward guidance quotes which are related to a different lift-off date or condition for the ZLB announced by the Fed. For an example, consider the quote announced on 6/19/2013 during the press conference by the former Chairman Bernanke.[47] Such forward guidance quote may influence market participants to expect a delay in the lift-off date of the ZLB and consequently continuation of passive monetary policy regime in the future periods. It can be seen clearly that the new monetary policy factor starts to decrease at 2013:3 after the 6/19/2013 announcement, which may be due to the market's updated expectation that the central bank may keep the current passive policy stance at least for the next several periods.

Figures 30-33 present the time varying policy interactions obtained from TVC-VAR analysis implemented with the new monetary policy factor based on the new policy rate i_t^* and the fiscal regime factor.[48] Again we observe similar patterns of time varying policy interactions in terms of both magnitudes and signs to those obtained from our earlier TVC-VAR analysis implemented with the original monetary factor based on i_t. One noticeable difference is the response of monetary regime factor to the fiscal regime shock after mid 2000. When the fiscal regime becomes active

[47]The quote states "...14 of 19 FOMC participants indicated that they expect the first increase in the target for the federal funds rate to occur in 2015, and one expected the first increase to incur in 2016."

[48]We consider TVC-VAR(3) instead of TVC-VAR(2) here since TVC-VAR(2) gives a small bandwidth and relatively hard to capture the low frequency interactions between two policy regime factors. Except for the order of VAR, we follow the same specification for TVC-VAR estimation considered in Section 3.

with a negative one standard deviation shock, the monetary regime factor becomes active initially (but briefly) and then becomes passive. The magnitude of response is smaller than our original response function but still the effect of fiscal regime shock remains persistently.

6 Conclusion

Monetary and fiscal regimes display strong dynamic interactions in postwar U.S. data. Estimating the *endogenous* nature of the evolution of policy regimes is essential to this conclusion: it points research toward understanding how the central bank's choice of monetary rule influences the government's choice of fiscal rule and vice versa. Modeling regime change as endogenous also sheds light on how macroeconomic developments affect systematic policy behavior.

Three key findings emerge. First, estimated policy coefficient imply that monetary and fiscal policy behavior fluctuates between two theoretically interpretable regimes and that changes in one policy rule help to predict changes in the other policy rule. Second, government debt, the term structure of interest rates, and other macroeconomic variables exhibit strong dynamic correlations with estimated policy regime factors. Third, shocks to non-policy variables, particularly those associated with real economic activity, generate movements in policy regimes.

These findings suggest both that the econometric techniques that Chang et al. (2015) develop can uncover potentially important policy interactions and that those interactions bear more thorough economic analysis. The next step is to integrate the econometric methods with a fully-specified dynamic stochastic general equilibrium model. In such a model, the estimated latent factors may reflect agents' time-varying beliefs about the prevailing policy regime. As beliefs evolve over time, so too will agents' decision rules. Integration of the econometrics with the economic theory would permit joint estimation of the parameters associated with the endogenous switching process and with economic behavior.

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Appendix

Appendix A: Endogenous and Conventional Regime Switching Models

We compare estimates from our endogenous regime switching model with those from the conventional regime switching model in previous empirical studies. Mainly, we consider Davig and Leeper (2006b), which will be referred to as DL hereafter. DL estimate exogenous regime switching monetary and fiscal policy rules using U.S. data from 1948:2 to 2004:1. Their model includes output gap and heterogenous errors in their specification unlike ours, so it is hard to compare estimates directly. Except the 1960s, our estimated monetary policy regime is consistent with their estimated state distribution. In our result, estimated monetary policy regime is active in 1962-1970 but estimates in DL imply that monetary policy is passive during that period. For the fiscal policy, our results are also similar to estimates in DL except the 1960s. Fiscal policy regime is passive in our endogenous regime switching estimates, but DL estimate this period as mainly active.

We also compare estimates from our endogenous regime switching model with those from the conventional regime switching model which is corresponding to our specification. If we found differences in estimated state distribution, there are two possible sources which generate differences. First, introducing endogeneity may induce a difference. Second, the different way of state identification can be a source of a difference. A state in our endogenous regime switching model is identified depending upon whether the extracted latent factor is greater than the estimated threshold whereas a state in the conventional regime switching model is identified depending upon whether the inferred probability is greater than 0.5. However, the latter source may not generate the main difference in estimated state distribution once filtered or smoothed probabilities are far from 0.5. Figures 38 and 39 present comparisons between the estimated state distribution from the endogenous regime switching policy rules and that from the conventional markov switching policy rules corresponding to our specification. In the case of monetary policy rule, estimated state distributions from endogenous regime switching and conventional regime switching models are overlapped mainly with minor differences.

The estimated state distribution for the fiscal policy, however, shows more differences between endogenous regime switching and conventional regime switching estimations. As shown in 39, the conventional regime switching model with our specification fails to capture some important fiscal events including Korean War in the 1950s, Clinton's tax hike in the 1990s and Bush tax cuts in the 2000s. Those differences mainly come from the introducing endogeneity in the model.[49]

The maximum log likelihood from the endogenous regime switching model is much higher than that from the corresponding exogenous regime switching model for MP and FP. Also, by comparing estimated state distributions from our endogenous regime switching with the conventional markov switching models under the same specification, we observe that estimates from endogenous regime switching model captures interpretable historical policy events more than the conventional markov

[49]Different ways of state identification make minor differences in the fiscal policy rule.

switching model. The endogenous switching model exploits the information from the past values of the observed time series to update the transition probability. Endogeneity in regime switching creates an important additional link between the latent states and observed time series. The information that can be channeled through this link cannot be exploited if we consider the exogenous regime switching model. We may need to consider other specifications of policy rule further for more clear comparison between our estimates and those from previous empirical studies including DL. However, this simple policy rule specification shows us how our endogenous regime switching model can work and give an inference about underlying policy regime.

Appendix B: Time Invariant VAR via Subsample Analysis

We consider a bivariate VAR with the monetary and fiscal regime factors to analyze the systematic interactions in policy rules. By considering possible policy implementation lags, we focus on the eighth order of VAR.[50] For identification of the VAR, we employ two different triangular schemes. First, we assume fiscal regime factor is contemporaneously affected by monetary regime factor but not vice-versa. In other words, monetary authority changes their policy stance first, and fiscal authority behaves later after they observe the monetary policy stance. Second, monetary regime factor is contemporaneously affected by fiscal regime factor but not in opposite direction. We also analyze the time variations in the policy interaction via subsample analysis. Here we consider two sample periods, full sample period (1949:2-2014:2) and sub-sample period (2000:2-2014:2) respectively. It is sensible that policy interactions have changed historically. Our VAR analysis for the full sample period may give an averaged relationship between two policy authorities during last 65 years. In the sub-sample analysis, we mainly include the period has asserted as the period which has apparent policy interaction with passive monetary and active fiscal policy regime. For the full sample period, average of monetary regime factor is 0.71 (active) and average of fiscal regime factor is -0.28 (passive). The sub-sample period, in contrast, average of monetary regime factor is -1.24 (passive) and average of fiscal regime factor is -3.79 (active) given thresholds.[51]

Based on the estimated VAR(8), we analyze the impulse responses for each of identification schemes. For each policy, we add one negative standard deviation shock from the estimated thresholds.[52] Note that the level information about the latent factors is important in the determination of each regime given thresholds. For the shock on a policy, we observe that the other policy is changed in the direction which is consistent with a theoretical prediction of price level determination. For instance, if MP regime becomes passive with a shock in monetary policy regime, fiscal regime factor

[50] We consider VARs with various lags, and we find that the estimation results are quite stable for VAR(r) with $r \geq 5$.

[51] The correlation between extracted monetary and fiscal regime factors during the subsample period is 0.77 which is greater than 0.48 in the full sample period. We compare the averaged interaction between MP and FP in the full sample and subsample periods by considering the whole extracted policy regime factors and the last part of extracted policy regime factors, respectively.

[52] Our impulse response function starts from estimated thresholds for a convenient description of the direction and magnitude of responses.

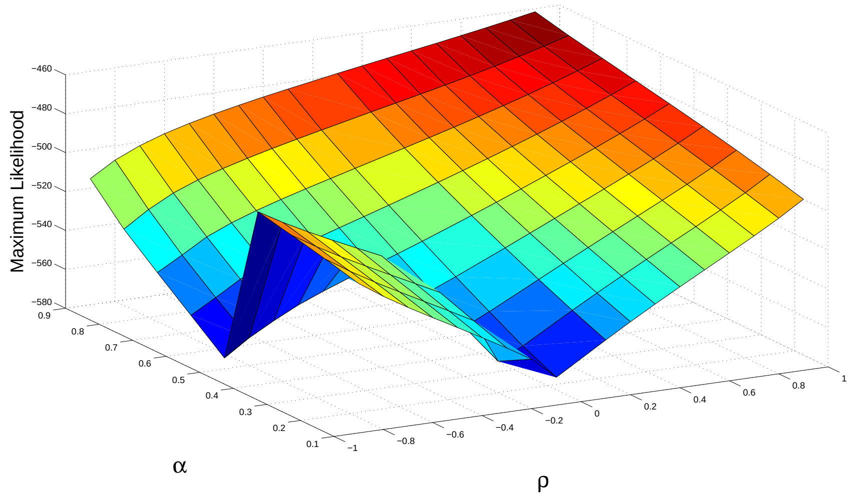
decreases and fiscal policy becomes active. Regardless of the ordering of variables, we have similar and intuitive impulse response functions except the impulse response in monetary policy regime to shock on fiscal regime. When FP regime becomes active with a shock in fiscal regime, monetary policy becomes passive. However, the response of monetary policy regime to the change in fiscal regime is a little unclear with wider error bands and small magnitudes. Figures 34-35 show impulse response functions of VAR(8) with 90% confidence interval error bands for the full sample period. Under the 5 % significant level, Granger causality test rejects the null hypothesis that monetary policy factor does not Granger cause fiscal policy factor and cannot reject the null that fiscal policy factor does not Granger cause monetary policy factor.

Figures 36-37 present impulse response functions of VAR(8) for the sub-sample period. According to impulse response functions, monetary and fiscal authorities seem like respond to each others' regime switching clearer, especially for the response of monetary policy regime to shock to fiscal regime. Contrast to full sample period analysis, Granger causality test rejects the null hypothesis that fiscal policy factor does not Granger cause monetary policy factor and reject the null that monetary policy factor does not Granger cause fiscal policy factor under the 5 % significant level.

We observe that when monetary policy regime becomes more active, fiscal policy regime tends to be more passive and vice versa in both sample period. Also, we find the time varying interactions between two policy authorities by comparing the full sample and the subsample period. Especially, monetary policy regime responses weakly to a change in fiscal policy regime in the full sample period, whereas in the subsample period, monetary policy regime responses strongly to a change in fiscal policy regime with the large response and narrow error band as shown in Figures 34 and 36. Overall, the policy interaction between MP and FP tends to be stronger and clearer during the subsample period.

Appendix C: Tables and Figures

Figure 1: Profile Likelihood for Endogenous Regime Switching Monetary Policy Model

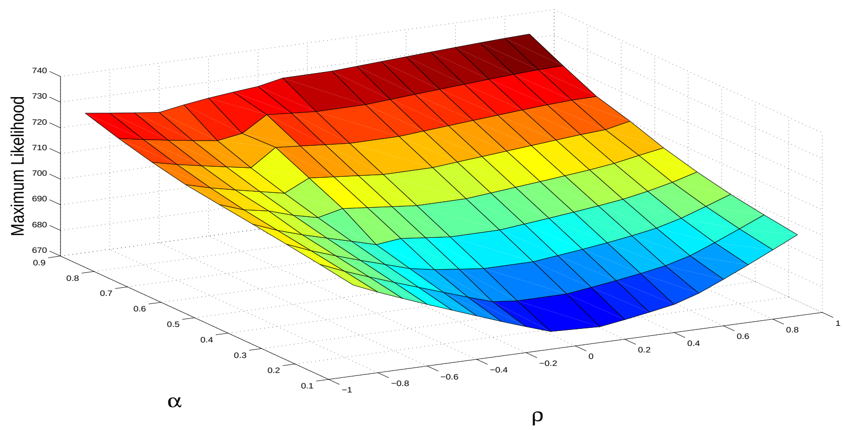


Notes: Figure 1 shows the surface plot of the joint profile likelihood of α_m and ρ_m from our endogenous regime switching monetary policy model obtained by profiling out all the other remaining parameters.

Table 1: Estimation Results for Endogenous Regime Switching Monetary Policy Model

	Endogenous		Exogenous	
Parameter	Estimate	S.E	Estimate	S.E
α_m	0.983	(0.012)	0.993	(0.004)
ψ_m	-0.871	(1.843)	-1.068	(3.346)
ρ_m	0.999	(0.0001)		
$a_c(s_t^m = 0)$	0.459	(0.278)	0.175	(0.289)
$a_c(s_t^m = 1)$	2.605	(0.267)	2.394	(0.210)
$a_\pi(s_t^m = 0)$	0.660	(0.067)	0.691	(0.067))
$a_\pi(s_t^m = 1)$	1.039	(0.062)	1.075	(0.053)
σ^m	1.307	(0.0597)	1.301	(0.060)
log-likelihood	-456.259		-468.157	
p-value(LR test for $\rho_m = 0$)	0.00000107			

Figure 2: Profile Likelihood for Endogenous Regime Switching Fiscal Policy Model



Notes: Figure 2 shows the surface plot of profile likelihood from our endogenous regime switching fiscal policy model obtained by profiling out all the parameters but α_f and ρ_f.

Table 2: Estimation Results for Endogenous Regime Switching Fiscal Policy Model

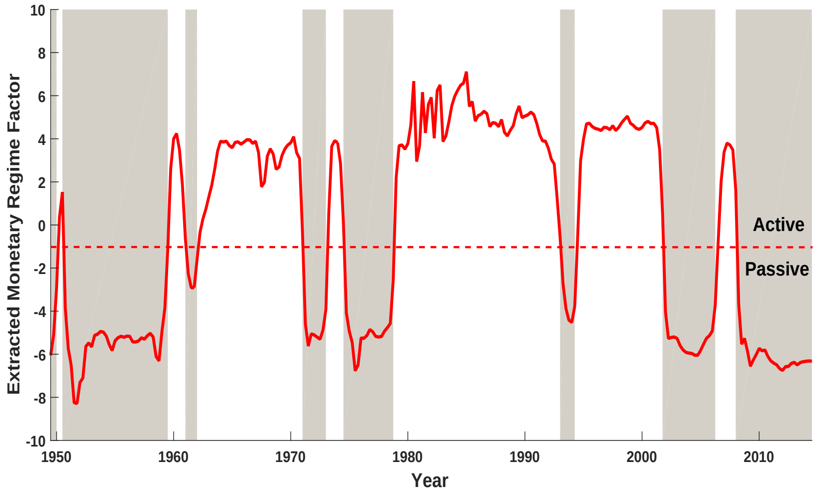
	Endogenous		Exogenous	
Parameter	Estimate	S.E	Estimate	S.E
α_f	0.970	(0.020)	0.990	(0.009)
ψ_f	-0.530	(1.185)	-3.007	(2.931)
ρ_f	0.990	(0.025)		
$\beta_c(s_t^f = 0)$	-0.028	(0.011)	-0.098	(0.022)
$\beta_c(s_t^f = 1)$	0.012	(0.007)	0.007	(0.005)
$\beta_b(s_t^f = 0)$	-0.008	(0.002)	-0.002	(0.003))
$\beta_b(s_t^f = 1)$	0.014	(0.002)	0.016	(0.004)
$\beta_g(s_t^f = 0)$	1.027	(0.093)	1.612	(0.172))
$\beta_g(s_t^f = 1)$	0.602	(0.052)	0.580	(0.052)
σ^f	0.014	(0.0006)	0.014	(0.0006)
log-likelihood	727.626		720.887	
p-value(LR test for $\rho_f = 0$)	0.00024			

Table 3: Implied Averages of Variables Conditional on Regime

Variables	Regime	Average
T-Bill Rate	Active	6.11
	Passive	2.43
Inflation Rate	Active	3.39
	Passive	3.01
Tax/GDP	Active	0.06
	Passive	0.10
Debt/GDP	Active	0.38
	Passive	0.33
Govt.Spending/GDP	Active	0.10
	Passive	0.11

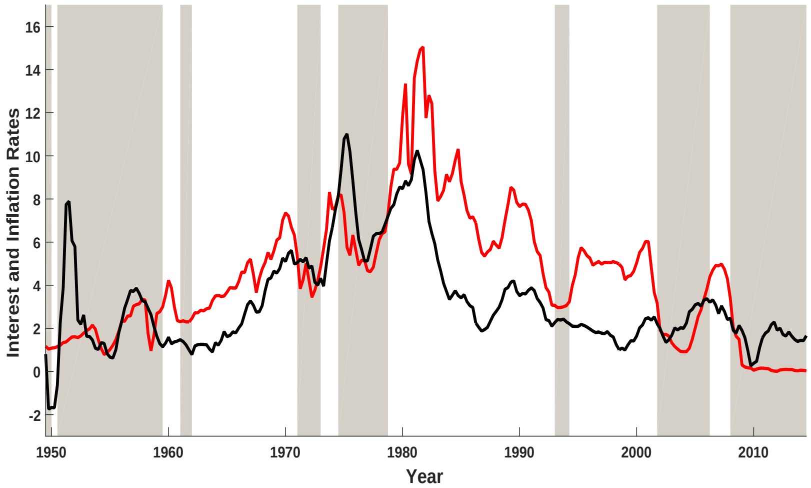
Notes: Table 3 reports the implied averages of variables used in estimations of MP and FP rules conditional on regime. Average inflation, debt/GDP and government spending ratios are calculated from actual data conditional on regime, and implied averages of interest rate and tax/GDP ratio are calculated by plugging those averaged variables by regime and regime dependent intercept terms into the policy rules.

Figure 3: Extracted Monetary Policy Factor (w_t^m) and Estimated State Distribution



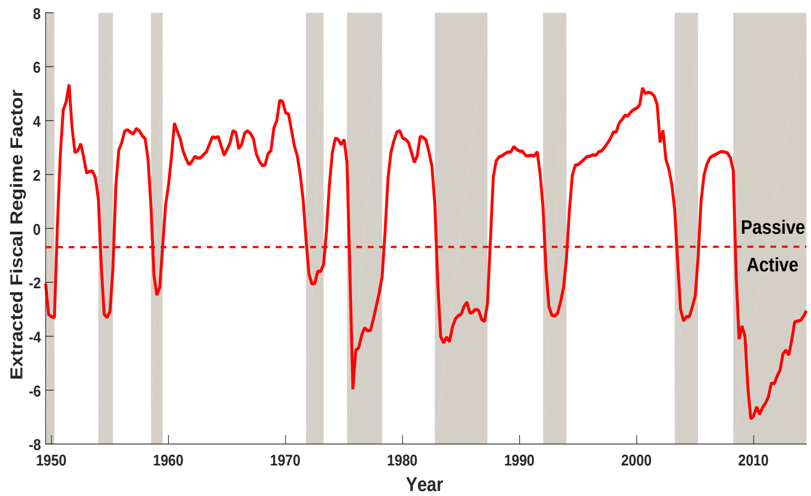
Notes: Figure 3 presents the extracted monetary policy factor (w_t^m) and estimated state distribution. Solid line is the extracted policy factor from monetary policy rule and dashed line is estimated threshold (-0.87), and shaded area is the estimated passive MP regime where the extracted monetary policy factor is below the threshold.

Figure 4: Monetary Policy Data and Estimated State distribution



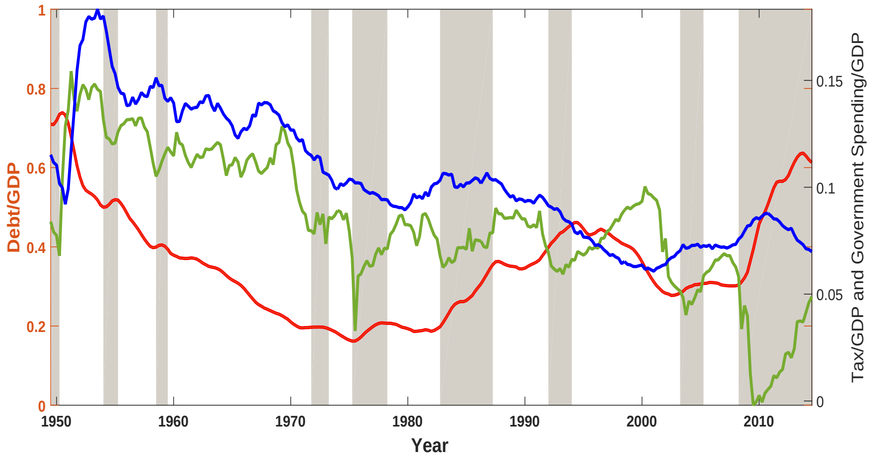
Notes: Figure 4 shows T-bill rate and inflation rate used in our estimation and estimated state distribution. Red line is T-bill rate, black line is inflation rate, and shaded area is the estimated as passive monetary policy regime, $w^m < \psi_m$.

Figure 5: Extracted Fiscal Policy Factor (w_t^f) and Estimated State Distribution



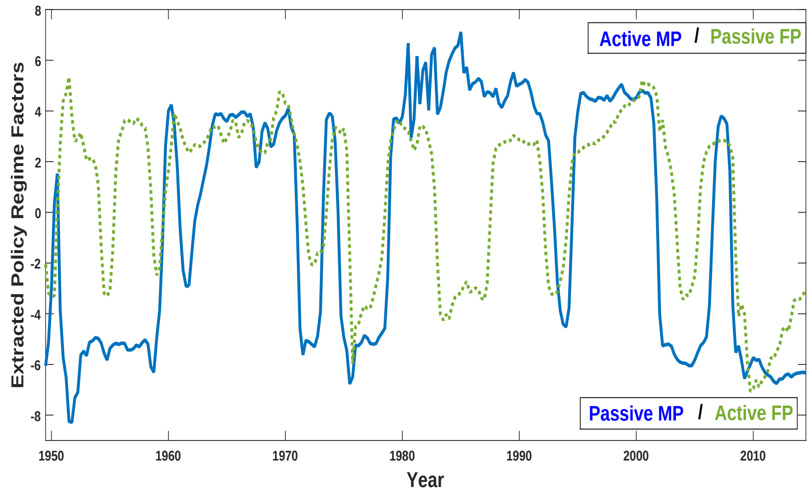
Notes: Figure 5 presents the extracted fiscal policy factor (w_t^f) and estimated state distribution. Solid line represents the extracted policy factor from fiscal policy rule and dashed line is the estimated threshold (-0.53), and shaded area is the estimated active FP regime where the extracted fiscal policy factor is below the threshold.

Figure 6: Fiscal Policy Data and Estimated State Distribution



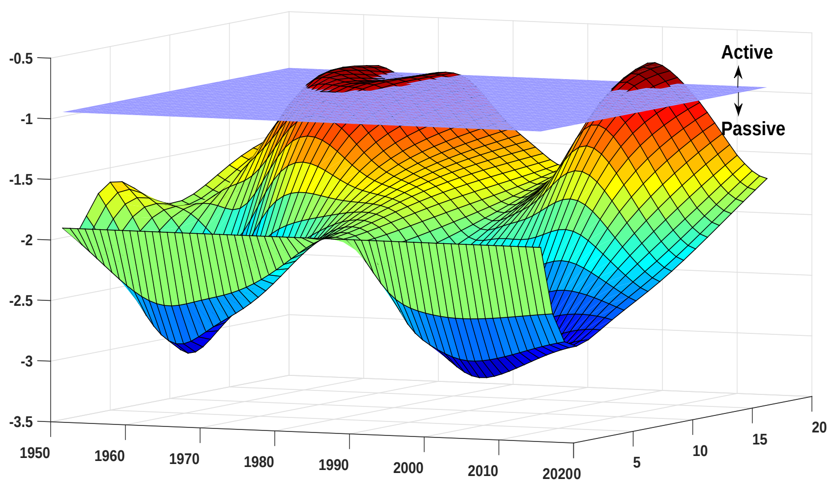
Notes: Figure 6 plots the fiscal variables used in our estimation and estimated state distribution. Green line represents tax/GDP ratio, blue line is government spending/GDP ratio, orange line is debt/GDP ratio, and shaded area is the estimated active FP regime.

Figure 7: Extracted Policy Factors from Policy Coefficient Switching Models



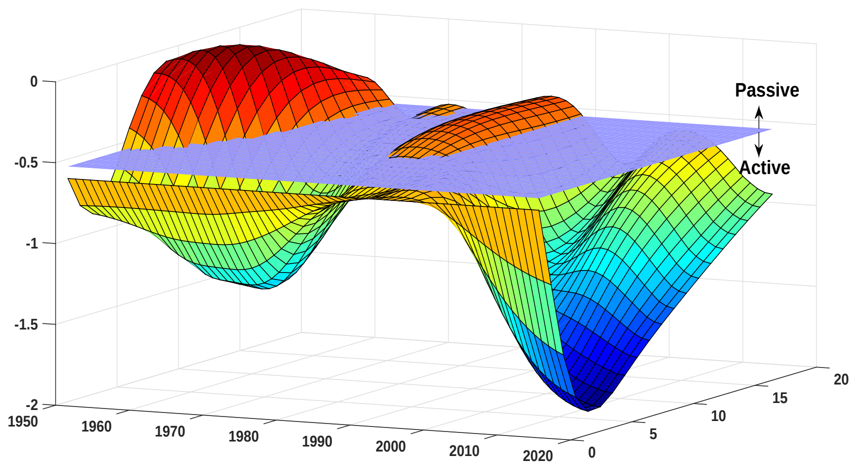
Notes: Solid blue line is the extracted policy factor from MP model and dashed green line represents the extracted policy factor from FP model. The correlation is 0.43.

Figure 8: IRF of MP Factor to MP Regime Shock in TVC-VAR



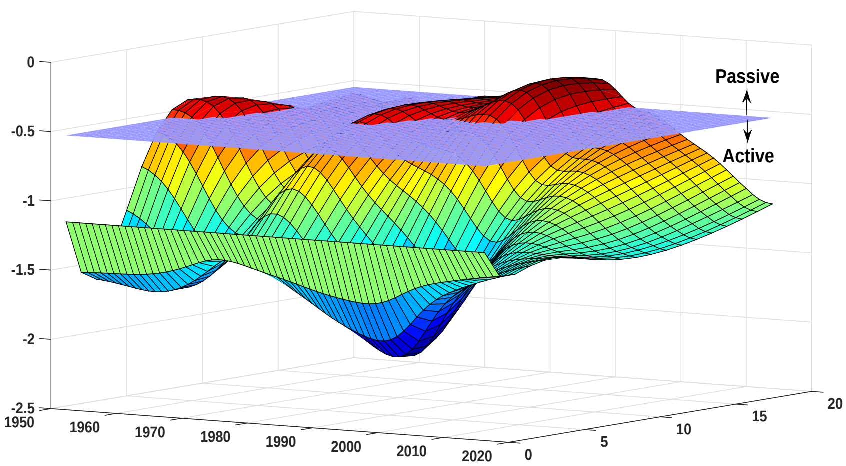
Notes: Order of variables is MP factor first and FP factor later. Blue transparent surface represents the estimated threshold for monetary policy (-0.87). The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of MP factor to a negative one standard deviation shock to MP regime.

Figure 9: IRF of FP Factor to MP Regime Shock in TVC-VAR



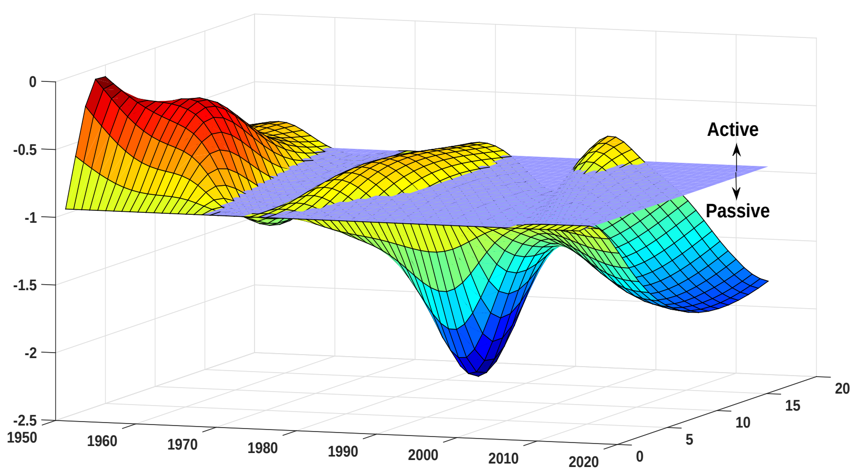
Notes: Order of variables is MP factor first and FP factor later. Blue transparent surface represents the estimated threshold for fiscal policy (-0.53). The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of FP factor to a negative one standard deviation shock to MP regime.

Figure 10: IRF of FP Factor to FP Regime Shock in TVC-VAR



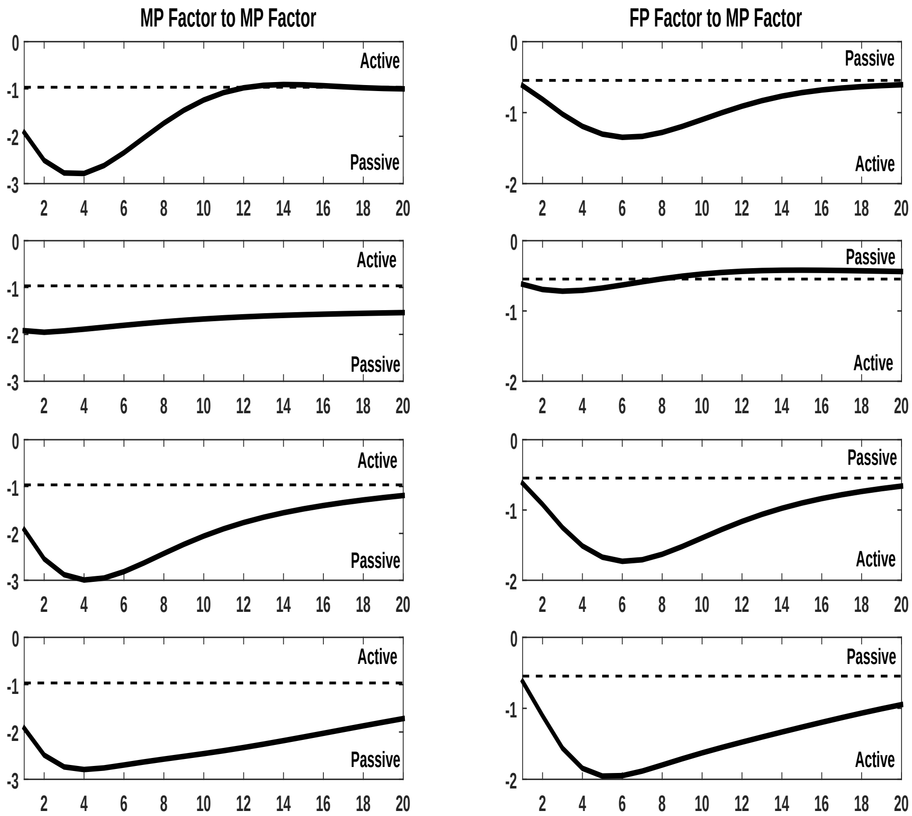
Notes: Order of variables is MP factor first and FP factor later. Blue transparent surface represents the estimated threshold for fiscal policy (-0.53). The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of FP factor to a negative one standard deviation shock to MP regime.

Figure 11: IRF of MP Factor to FP Regime Shock in TVC-VAR



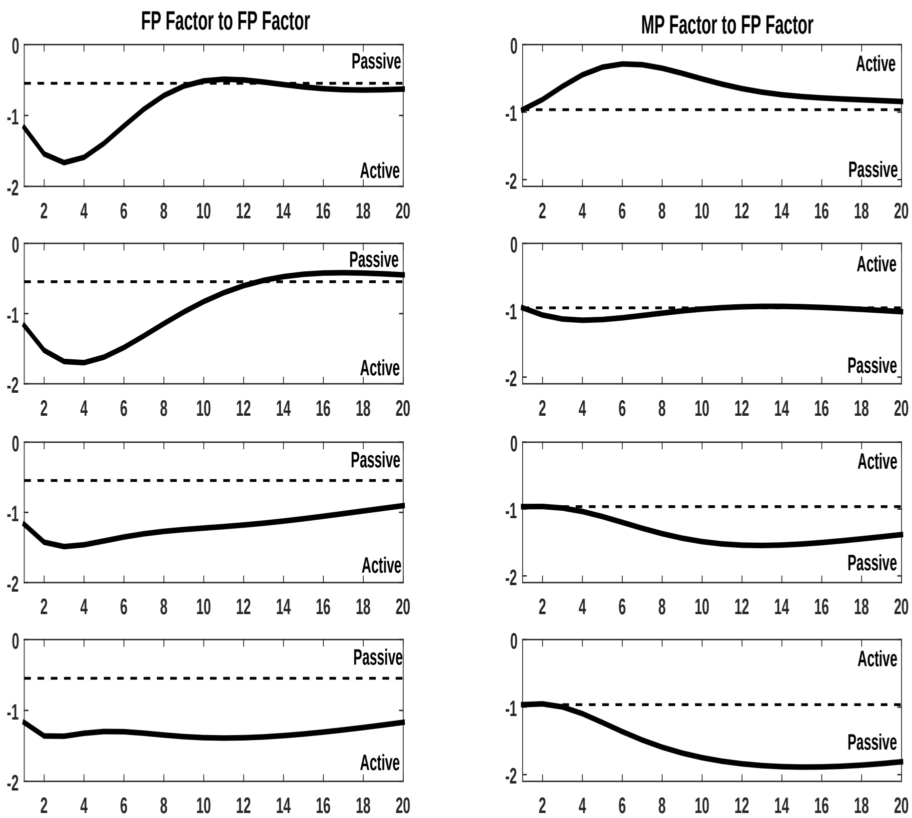
Notes: Order of variables is MP factor first and FP factor later. Blue transparent surface represents the estimated threshold for monetary policy (-0.87). The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of MP factor to a negative one standard deviation shock to FP regime.

Figure 12: IRF of MP Regime Shock on Selected Years



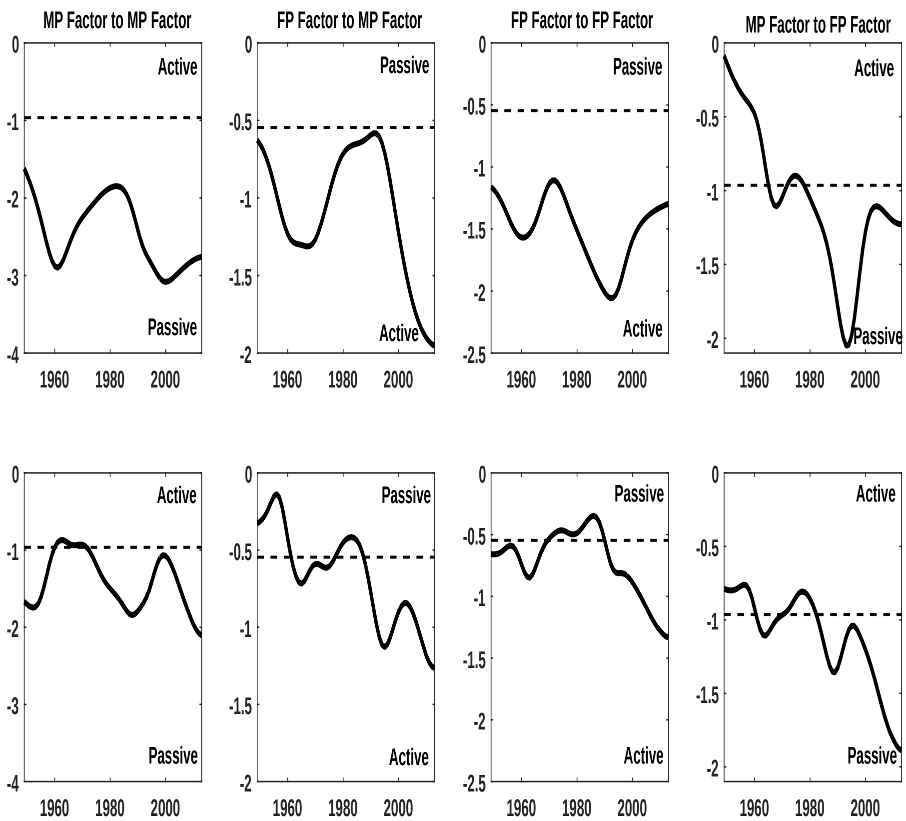
Notes: Order of variables is MP factor first and FP factor later. The first column represents the impulse response of MP factor to MP regime shock and the dotted straight line is the estimated threshold for monetary policy (-0.87). The second column represents the impulse response of FP factor to MP regime shock. The dotted straight line is the estimated threshold for fiscal policy (-0.53). The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a negative one standard deviation shock to MP regime. Each row shows the impulse response of MP regime shock in different years. Considered years are (the first quarter of) 1965, 1982, 2008, 2013 from top to bottom rows.

Figure 13: IRF of FP Regime Shock on Selected Years



Notes: Order of variables is MP factor first and FP factor later. The first column represents the impulse response of FP factor to FP regime shock and the dotted straight line is the estimated threshold for fiscal policy (-0.53). The second column represents the impulse response of MP factor to FP regime shock. The dotted straight line is the estimated threshold for monetary policy (-0.87). The x-axis represents quarters after the shock, the y-axis represent the value of the responses to a negative one standard deviation shock to FP regime. Each row shows the impulse response of FP regime shock in different years. Considered years are (the first quarter of) 1955, 1982, 2008, 2013 from top to bottom rows.

Figure 14: IRF of Policy Regime Shocks on Selected Horizons



Notes: Order of variables is MP factor first and FP factor later. The four columns represent IRFs of MP factor to MP regime shock, IRFs of FP factor to MP regime shock, IRFs of FP factor to FP regime shock and IRFs of MP factor to FP regime shock from left to right. Dotted straight lines are estimated threshold levels of the responding policy factors. The x-axis represents the time periods of the initial policy regime shock. The y-axis represents the value of the response to a negative one standard deviation shock to policy factors. The first and second rows show the values of the responses after 5 and 15 quarters respectively from the initial shock.

Table 4: Selected Macroeconomic Variables for MP Factor

Series	Est.Coeff	s.e	Category
6MTBR	3.41	0.87	Interest rate
Tax/GDP ratio	1.68	0.37	Fiscal
Average weekly hours: manufacturing	1.09	0.31	Employment and hours
Net interest payment/ Govt.outlays	0.84	0.25	Fiscal
Index of consumer expectations	0.61	0.25	Miscellaneous
NAPM vendor deliveries index	0.55	0.18	Real inventories and orders
Extracted fiscal policy factor	0.38	0.27	Fiscal
Moody's Baa bond yield-FFR	-0.41	0.30	Interest rate
All employees	-0.55	0.25	Employment and hours
Producer price index: finished goods	-0.59	0.30	Price indexes
NAPM new orders index	-0.61	0.25	Real inventories and orders
Housing starts: midwest	-0.84	0.42	Housing starts and sales

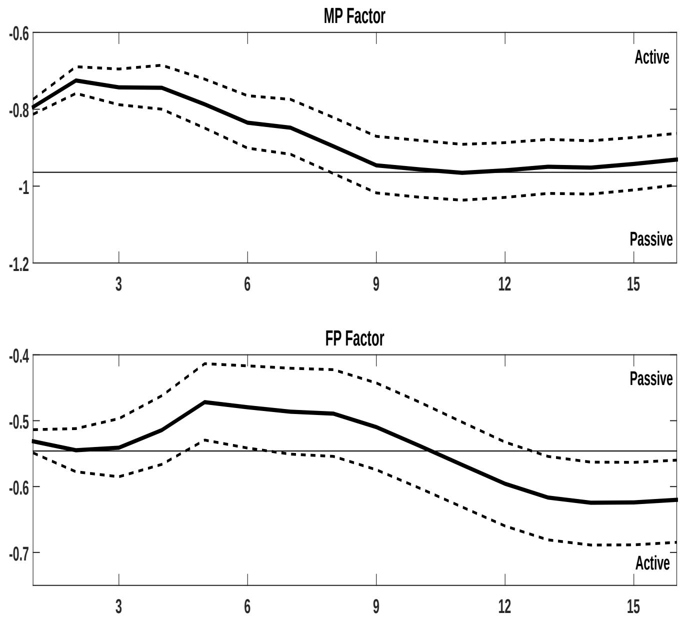
Notes: Table 4 presents selected 12 variables with larger coefficients for the MP regime factor. Estimated coefficients and standard errors are from the OLS estimation with selected variables.

Table 5: Selected Macroeconomic Variables for FP Factor

Series	Est.Coeff	s.e	Category
Extracted monetary policy factor	1.27	0.16	Monetary
Housing starts: midwest	0.84	0.18	Housing starts and sales
Average hourly earning: construction	0.71	0.15	Employment and hours
Output gap	0.46	0.21	Real output and income
Civilians unemployed: 15 weeks and over	0.39	0.19	Employment and hours
M1 money stock	0.11	0.49	Money and credit
Consumer loans at all commercial banks	-0.23	0.11	Money and credit
All employees: retail trade	-0.47	0.18	Employment and hours
Employees on nonfarm payrolls: manufacturing	-0.50	0.20	Employment and hours
Total checkable deposits	-0.93	0.48	Employment and hours
Net interest payment/Debt ratio	-0.94	0.17	Fiscal
Moody's Baa bond yield-FFR	-1.14	0.18	Interest rate

Notes: Table 5 presents selected 12 variables for the FP regime factor. Estimated coefficients and standard errors are from the OLS estimation with selected variables.

Figure 15: Responses of Policy Factors to MP Regime Shock in FAVAR



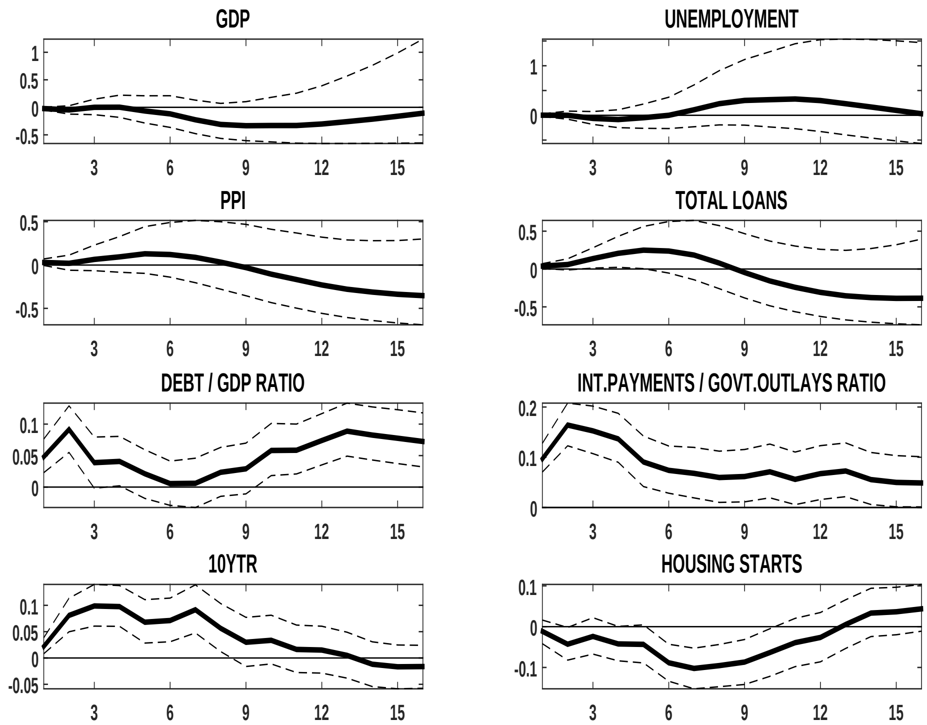
Notes: Figure 15 shows the impulse responses of policy factors to MP regime shock. The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a positive one standard deviation shock to MP regime. The upper and lower dotted lines represent the 90 % confidence intervals of impulse responses for policy factors.

Table 6: Contributions of MP Regime Shocks (%) to the Variance of Variables

Variables	Variance Decomposition	R^2
w^m	48.9	1*
w^f	5.2	1*
GDP	5.4	0.68
Unemployment	10.1	0.72
PPI	12.2	0.85
Total loans	10.1	0.62
Debt/GDP ratio	20.8	0.71
Int.payment/Govt.outlays ratio	51.6	0.64
10YTR	19.3	0.87
Housing Starts	8.4	0.61

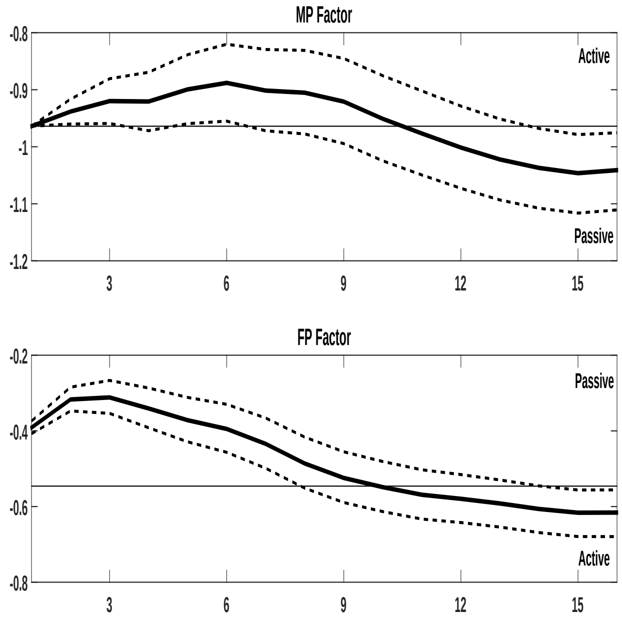
Notes: The columns report the fraction of the variance of the forecast error of the common component, at the 16 quarter horizons, explained by MP regime shock. R^2 refers to the fraction of the variance of the variable explained by the common components. $*$This is by construction.

Figure 16: Responses of Key Macro Variables to MP Regime Shock in FAVAR



Notes: Figure 16 shows the impulse responses of key macro variables to MP regime shock. The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a positive one standard deviation shock to MP regime. The upper and lower dotted lines represent the 90 % confidence intervals of impulse responses for key macro variables.

Figure 17: Responses of Policy Factors to FP Regime Shock in FAVAR



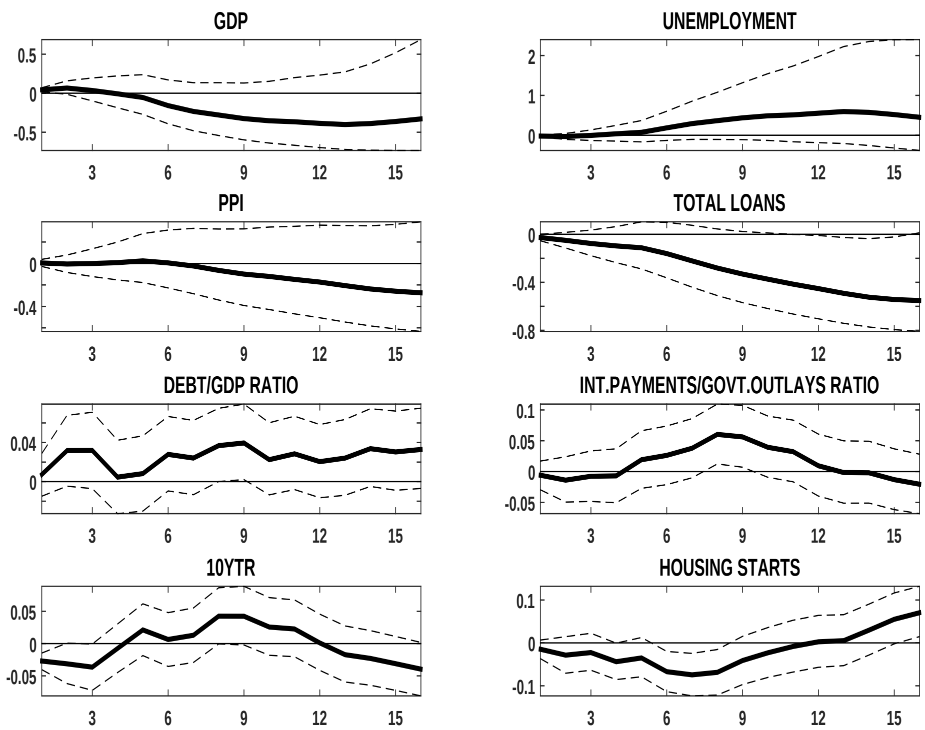
Notes: Figure 17 shows the impulse responses of policy factors to FP regime shock. The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a positive one standard deviation shock to FP regime. The upper and lower dotted lines represent the 90 % confidence intervals of impulse responses for policy factors.

Table 7: Contributions of FP Regime Shocks (%) to the Variance of Variables

Variables	Variance Decomposition	R^2
w^f	64.3	1*
w^m	4.6	1*
GDP	4.2	0.68
Unemployment	6.0	0.72
PPI	8.5	0.85
Total loans	4.0	0.62
Debt/GDP ratio	8.6	0.71
Int.payment/Govt.outlays ratio	3.4	0.64
10YTR	7.9	0.87
Housing Starts	7.0	0.61

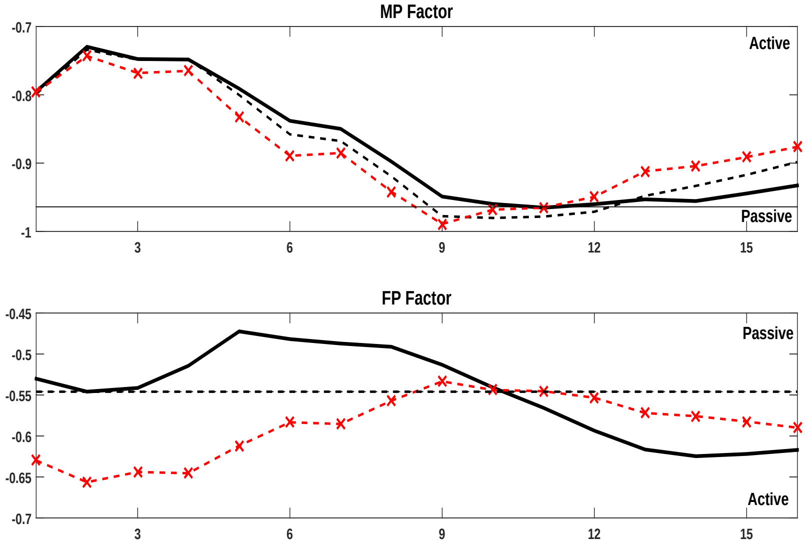
Notes: The columns report the fraction of the variance of the forecast error of the common component, at the 16 quarter horizons, explained by FP regime shock. R^2 refers to the fraction of the variance of the variable explained by the common components. $*$This is by construction

Figure 18: Responses of Key Macro Variables to FP Regime Shock in FAVAR



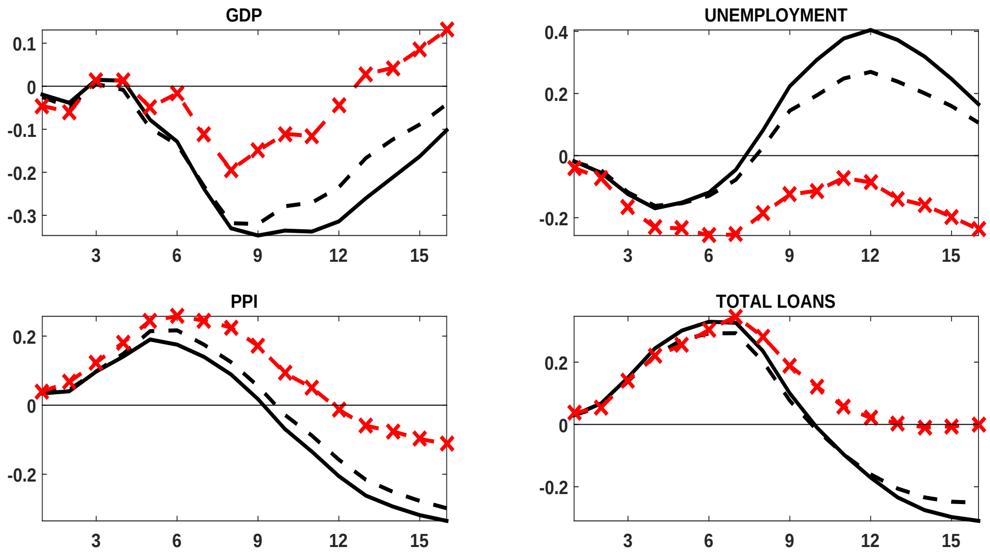
Notes: Figure 18 shows the impulse responses of key macro variables to FP regime shock. The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a positive one standard deviation shock to FP regime. The upper and lower dotted lines represent the 90 % confidence intervals of impulse responses for key macro variables.

Figure 19: Counterfactual Impulse Responses of Policy Factors to MP Regime Shock in FAVAR



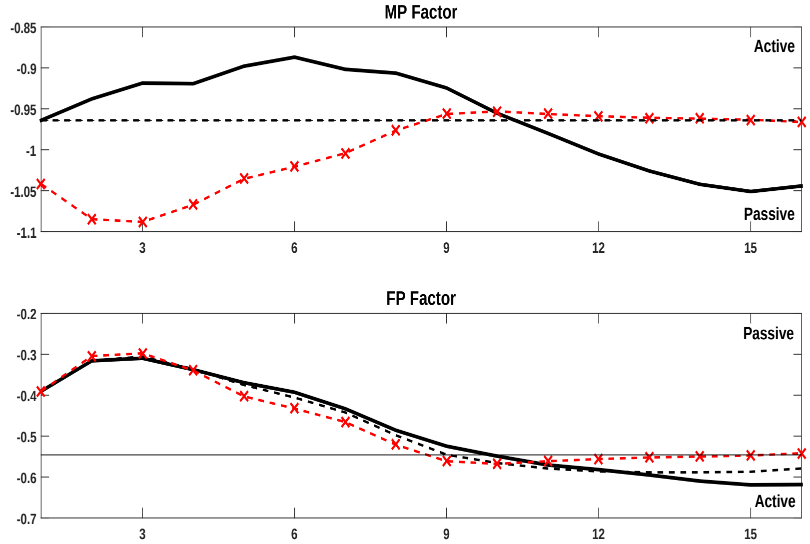
Notes: Figure 19 presents the counterfactual impulse responses of policy factors to a one positive standard deviation shock to MP regime under the scenario that fiscal policy regime does not respond or responds in opposite way to monetary policy regime change. IRFs of MP and FP factors to MP regime shock are plotted in the upper and lower panels, respectively. Solid lines signify the original responses, while dashed lines show the counterfactual responses when fiscal policy regime does not respond, and red dashed lines are the counterfactual responses when fiscal policy regime responses in opposite directions. Quarters after the shock are shown on the x-axis, and values of responses to policy factors on the y-axis.

Figure 20: Counterfactual Impulse Responses of Macro Variable to MP Regime Shock in FAVAR



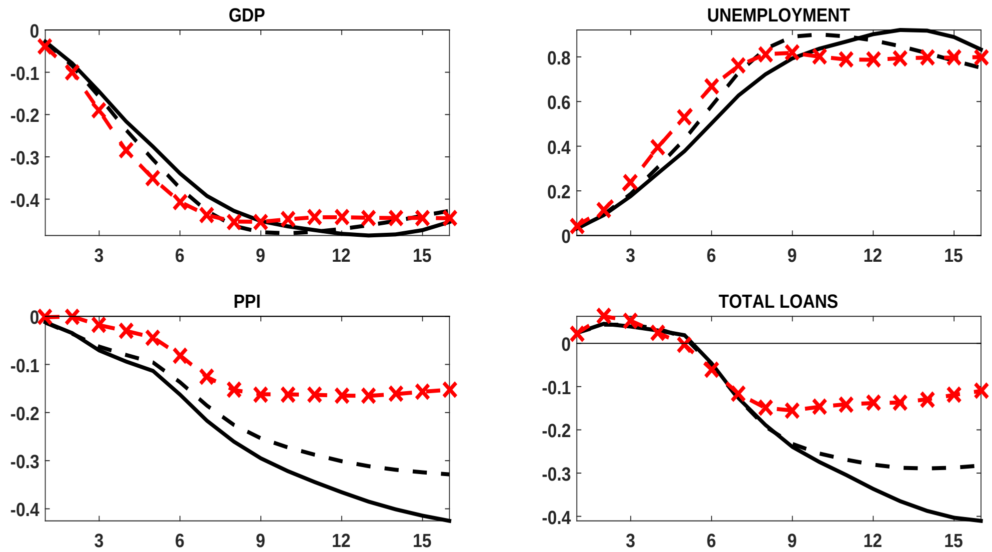
Notes: Figure 20 presents the counterfactual impulse responses of key macro variables to a one positive standard deviation shock to MP regime under the scenario that fiscal policy regime does not respond or responds in opposite way to monetary policy regime change. Solid lines signify the original responses, dashed lines the counterfactual response when fiscal policy regime does not respond, and red dashed lines the counterfactual responses when fiscal policy regime responds in opposite directions. Quarters after the shock are shown on the x-axis, and values of responses to macro variables on the y-axis.

Figure 21: Counterfactual Impulse Responses of Policy Factors to FP Regime Shock in FAVAR



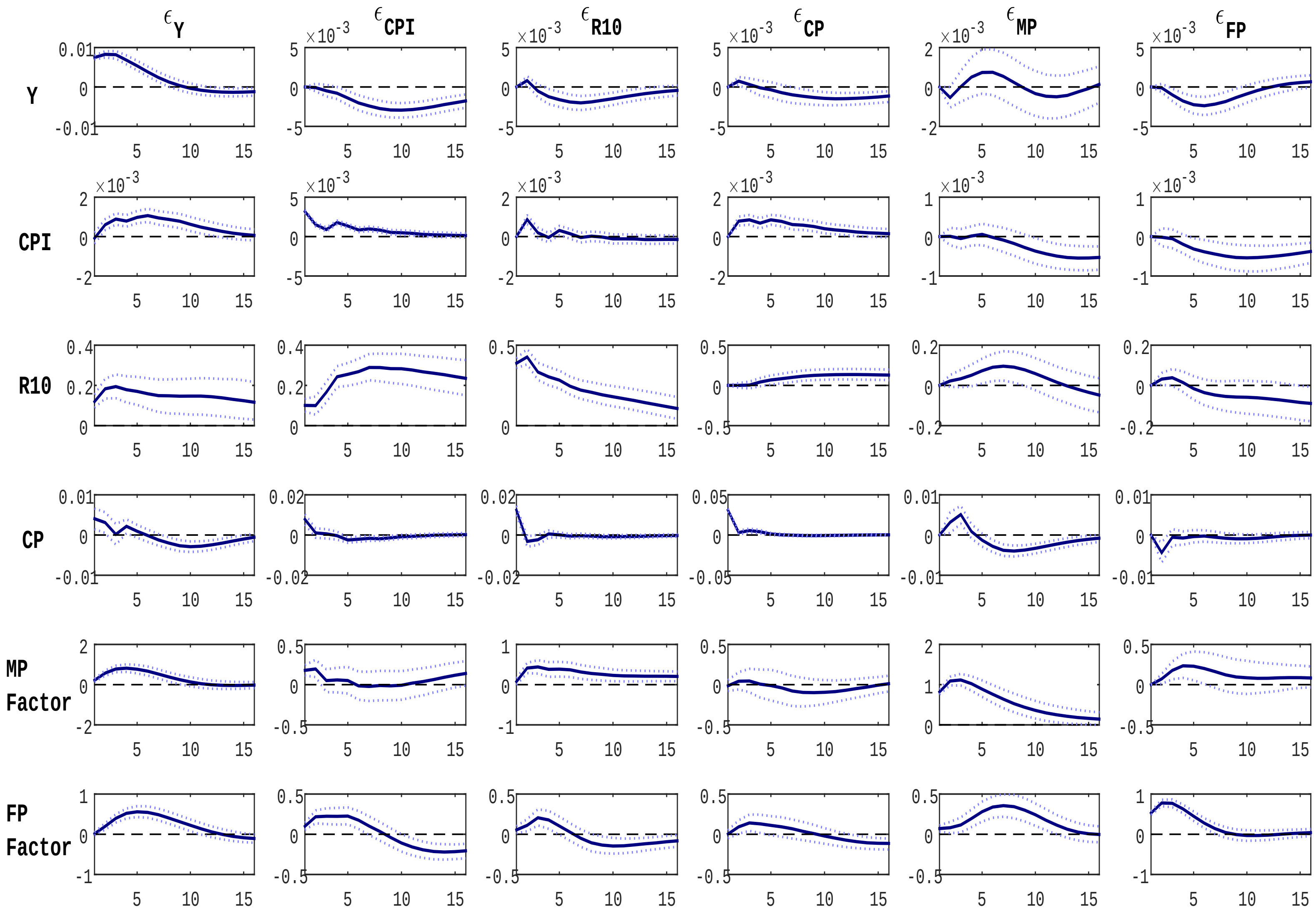
Notes: Figure 21 presents the counterfactual impulse responses of policy factors to a one positive standard deviation shock to FP regime under the scenario that monetary policy regime does not respond or responds in opposite way to fiscal policy regime change. IRFs of MP and FP factors to FP regime shock are plotted in the upper and lower panels, respectively. Solid lines signify the original responses, while dashed lines show the counterfactual responses when monetary policy regime does not respond, and red dashed lines are the counterfactual responses when monetary policy regime responses in opposite directions. Quarters after the shock are shown on the x-axis, and values of responses to policy factors on the y-axis.

Figure 22: Counterfactual Impulse Responses of Macro Variable to Shock to FP Regime in FAVAR



Notes: Figure 22 presents the counterfactual impulse responses of key macro variables to a one positive standard deviation shock to FP regime under the scenario that monetary policy regime does not respond or responds in opposite way to fiscal policy regime change. Solid lines signify the original responses, while dashed lines show the counterfactual responses when monetary policy regime does not respond, and red dashed lines are the counterfactual responses when monetary policy regime responses in opposite directions. Quarters after the shock are shown on the x-axis, and values of responses to macro variables on the y-axis.

Figure 23: Impulse Responses of All Variables in VAR Model



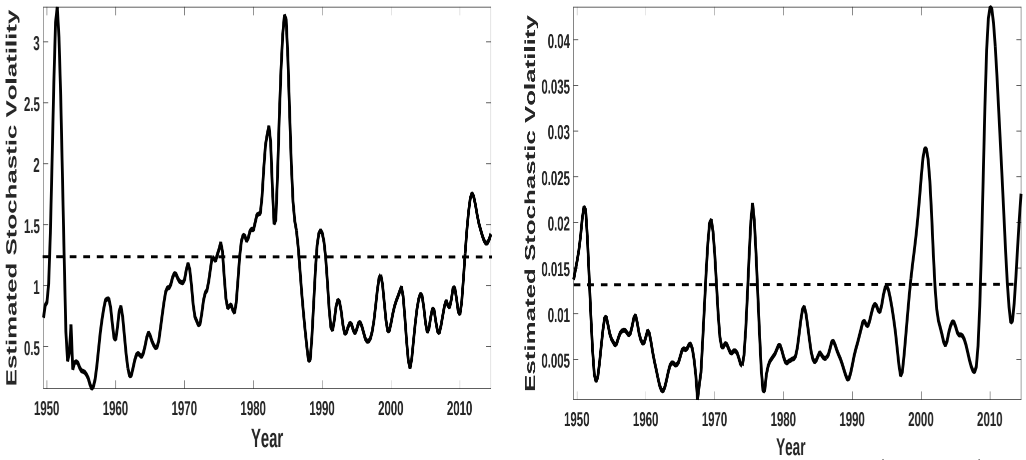
Notes: Figure 23 shows the impulse responses of six variables (Y, CPI, R10, CP, MP Factor, FP Factor) to the six structural shocks (ϵ_x, x=$Y, CPI, R10, CP, MP, FP$). The x-axis represents quarters after the shock, the y-axis represents the value of the responses to a positive one standard deviation shocks to variables. The upper and lower dotted lines represent the 70 % confidence intervals of impulse responses.

Table 8: Contributions of Structural Shocks (%) to the Variance of Variables

		Structural Shocks					
Variables	Horizons	ϵ_Y	ϵ_{CPI}	ϵ_{R10}	ϵ_{CP}	ϵ_{MP}	ϵ_{FP}
Y	8	82.3	0.3	3.1	1.6	1.0	11.8
	16	70.4	4.8	3.6	2.0	2.4	16.8
CPI	8	26.0	49.6	4.7	17.7	0.6	1.4
	16	21.8	35.9	3.9	14.9	13.8	9.7
R10	8	28.4	14.7	43.4	5.0	6.3	2.2
	16	33.1	27.6	24.3	8.3	4.5	2.2
CP	8	4.6	2.8	11.6	70.4	8.3	2.3
	16	5.3	3.4	10.7	64.0	13.8	2.9
MP	8	36.3	0.6	4.5	0.6	55.6	2.4
	16	31.3	1.5	3.8	4.3	55.4	3.6
FP	8	36.1	1.6	3.1	2.4	11.5	45.3
	16	31.1	1.7	8.6	11.1	12.9	34.7

Notes: Table 8 reports the variance decomposition of forecast errors of each of the variables. Each row represents the fraction of the variance of the variable explained by structural shocks at 8 and 16 quarter horizons respectively. The order of variables (structural shocks) is as follows: output gap-CPI-10 year T-bill rate-commodity price index-MP factor-FP factor.

Figure 24: Estimated Stochastic Volatility for Policy Rules



Notes: Figure 24 presents the estimated stochastic volatility for the monetary (the left) and fiscal (the right) policy rules. The stochastic volatility is estimated using a two-step approach and the HP filter with an appropriately chosen smoothing parameter.

Table 9: Results for Volatility Adjusted Endogenous Regime Switching Policy Models

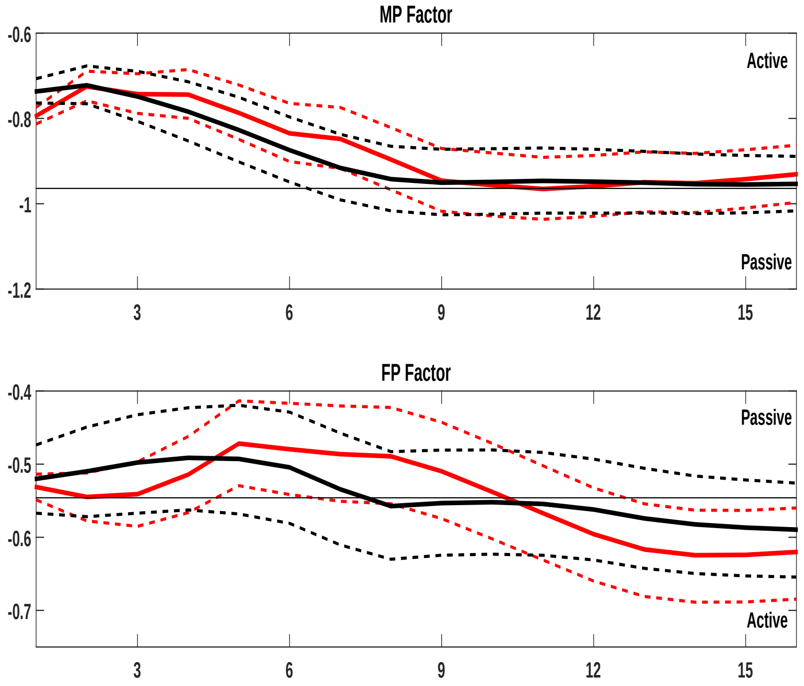
	Endogenous RS	
Parameter	Estimate	S.E
α_m	0.989	(0.006)
ψ_m	-0.856	(2.448)
ρ_m	0.993	(0.061)
$a_c(s_t^m = 0)$	0.615	(0.138)
$a_c(s_t^m = 1)$	2.133	(0.134)
$a_\pi(s_t^m = 0)$	0.649	(0.034)
$a_\pi(s_t^m = 1)$	1.068	(0.032)

(a) Estimates of monetary policy rule

	Endogenous RS	
Parameter	Estimate	S.E
α_f	0.972	(0.009)
ψ_f	-2.009	(2.190)
ρ_f	0.970	(0.001)
$\beta_c(s_t^f = 0)$	-0.010	(0.003)
$\beta_c(s_t^f = 1)$	0.012	(0.001)
$\beta_b(s_t^f = 0)$	-0.013	(0.007)
$\beta_b(s_t^f = 1)$	0.034	(0.005)
$\beta_g(s_t^f = 0)$	0.863	(0.017)
$\beta_g(s_t^f = 1)$	0.647	(0.013)

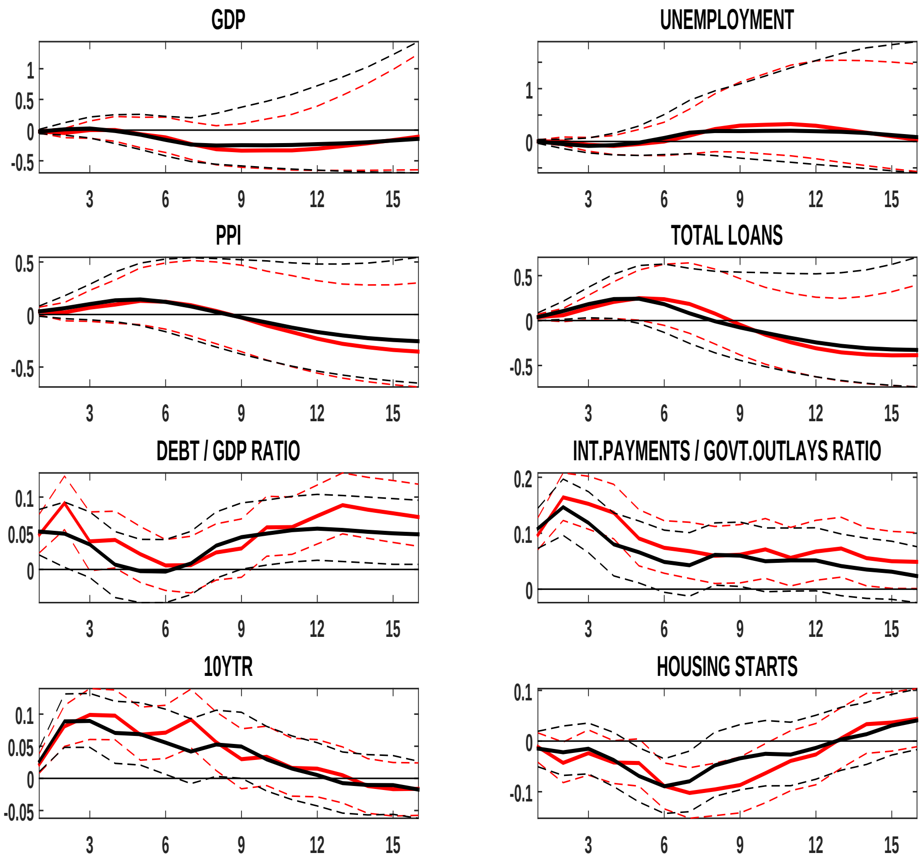
(b) Estimates of fiscal policy rule

Figure 25: Responses of Policy Factors to MP Regime Shock



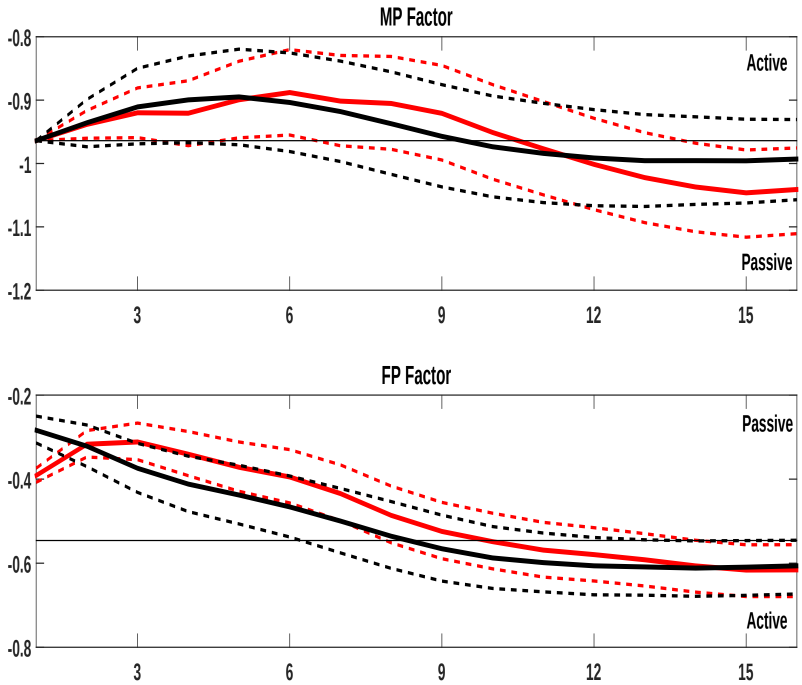
Notes: Figure 25 shows IRFs in solid line and their 90% confidence intervals in dotted lines of policy factors to MP regime shock. Red lines signify IRFs and their confidence intervals obtained by considering sampling variations only in principal components, while black lines represent those obtained by taking into account sampling variations in both principal components and estimated policy factors. Total number of resampled IRFs is 100,000.

Figure 26: Responses of Macro Variables to MP Regime Shock



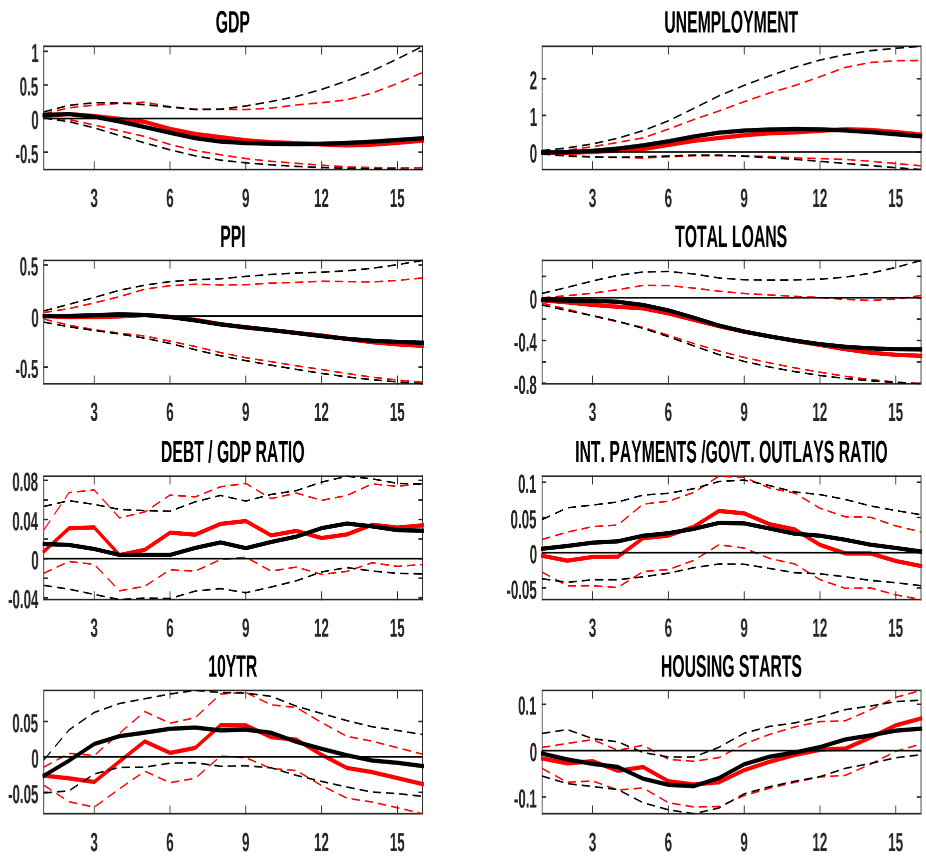
Notes: Figure 26 shows IRFs in solid line and their 90% confidence intervals in dotted lines of macro variables to MP regime shock. Red lines signify IRFs and their confidence intervals obtained by considering sampling variations only in principal components, while black lines represent those obtained by taking into account sampling variations in both principal components and estimated policy factors. Total number of resampled IRFs is 100,000.

Figure 27: Responses of Policy Regimes to FP Regime Shock



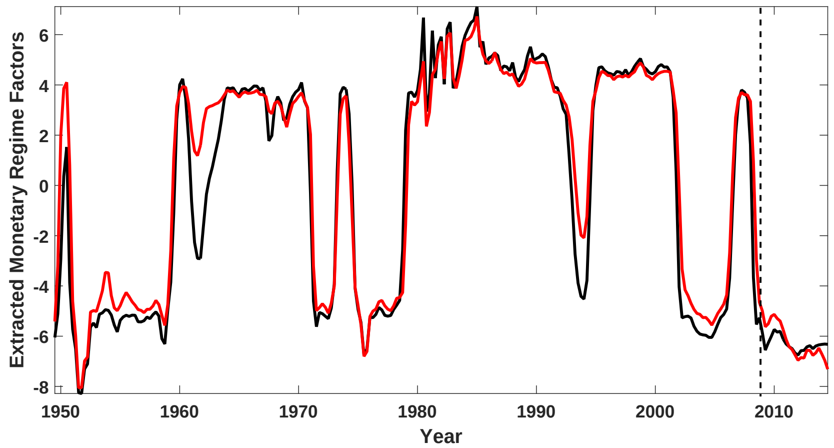
Notes: Figure 27 presents IRFs in solid line and their 90% confidence intervals in dotted lines of policy factors to FP regime shock. Red lines signify IRFs and their confidence intervals obtained by considering sampling variations only in principal components, while black lines represent those obtained by taking into account sampling variations in both principal components and estimated policy factors. Total number of resampled IRFs is 100,000.

Figure 28: Responses of Macro Variables to FP Regime Shock



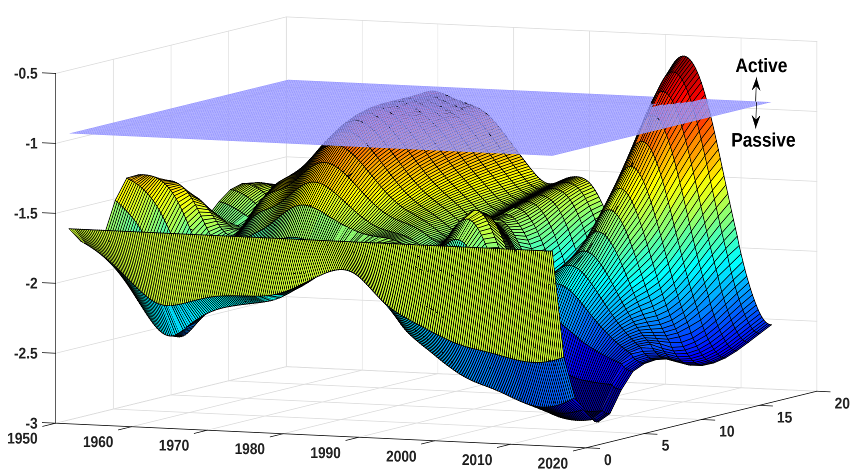
Notes: Figure 28 presents IRFs in solid line and their 90% confidence intervals in dotted lines of macro variables to FP regime shock. Red lines signify IRFs and their confidence intervals obtained by considering sampling variations only in principal components, while black lines represent those obtained by taking into account sampling variations in both principal components and estimated policy factors. Total number of resampled IRFs is 100,000.

Figure 29: Extracted Monetary Factors from i_t and i_t^*



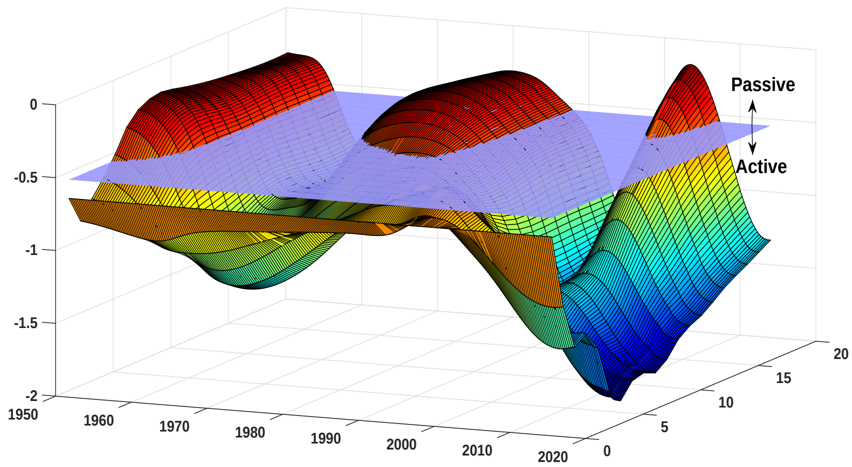
Notes: A new policy rate (i_t^*) is constructed as $(i_t^*) = \left((i_t)_{t\leq 2008:4}, (\hat{i}_t)_{t\geq 2009:1}\right)$, where i is the T-bill rate, and $\hat{i}$ is the estimated shadow rate by Wu and Xia (2015). The black line is the extracted monetary regime factor using i_t and the red line represents the extracted monetary policy factor using i_t^*.

Figure 30: IRF of MP Factor to MP Regime Shock in TVC-VAR with Shadow Rate



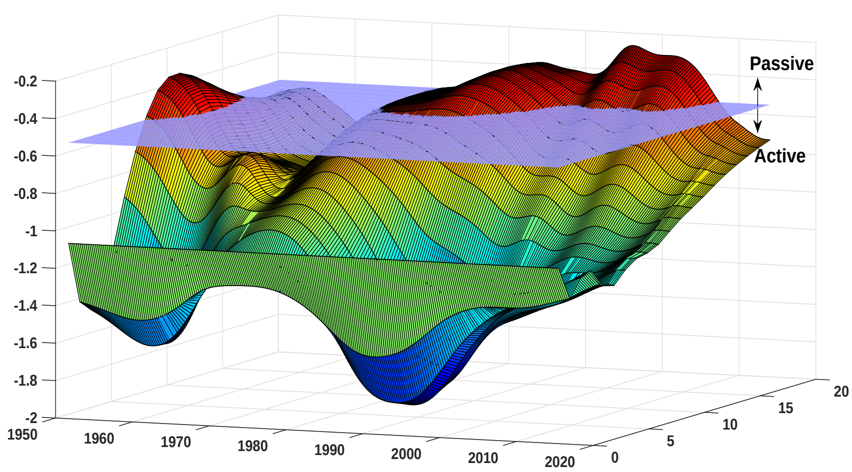
Notes: Monetary policy factor is estimated using a new policy rate (i_t^*). Blue transparent surface represents the estimated threshold for monetary policy. The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of MP factor to a negative one standard deviation shock to MP regime.

Figure 31: IRF of FP Factor to MP Regime Shock in TVC-VAR with Shadow Rate



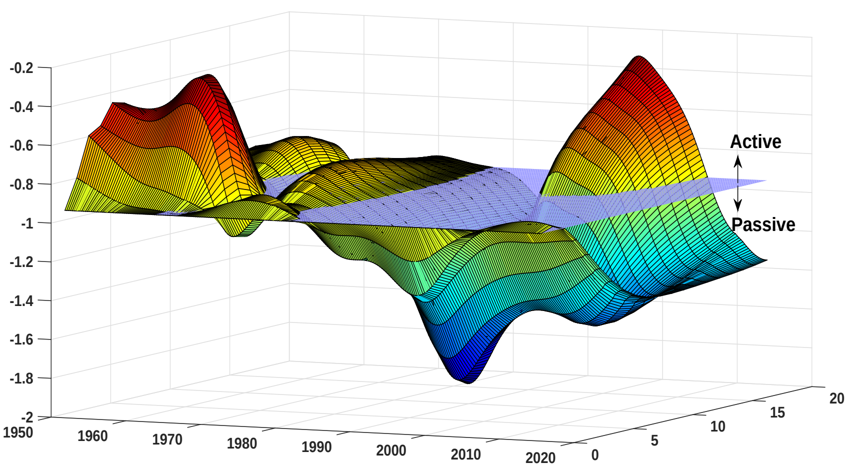
Notes: Monetary policy factor is estimated using a new policy rate (i_t^*). Blue transparent surface represents the estimated threshold for fiscal policy. The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of FP factor to a negative one standard deviation shock to MP regime.

Figure 32: IRF of FP Factor to FP Regime Shock in TVC-VAR with Shadow Rate



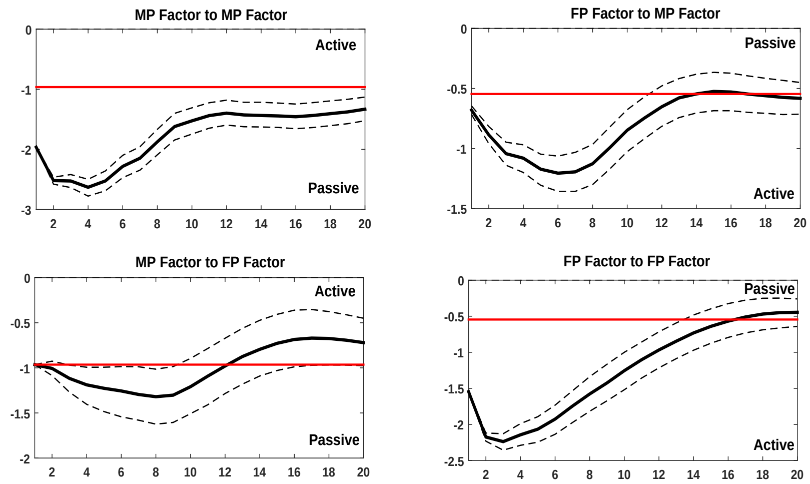
Notes: Monetary policy factor is estimated using a new policy rate (i_t^*). Blue transparent surface represents the estimated threshold for fiscal policy. The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of FP factor to a negative one standard deviation shock to FP regime.

Figure 33: IRF of MP Factor to FP Regime Shock in TVC-VAR with Shadow Rate



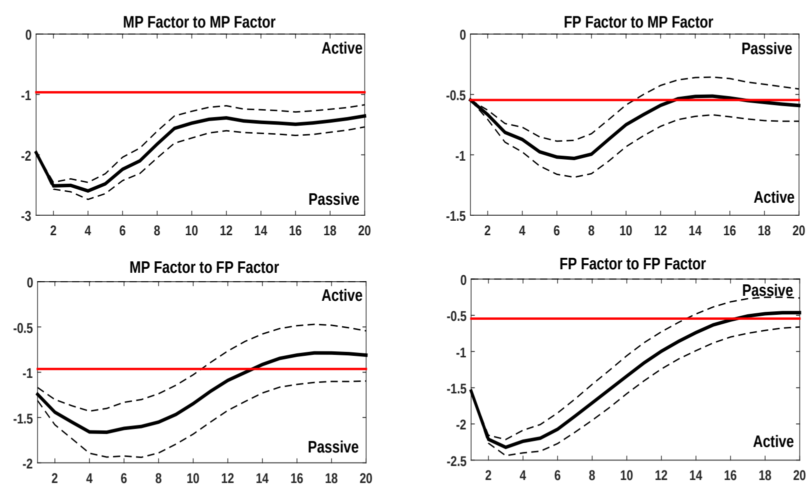
Notes: Monetary regime factor is estimated using a new policy rate (i_t^*). Blue transparent surface represents the estimated threshold for monetary policy. The x-axis represents quarters after the shock, y-axis represents the time periods from 1949:2 to 2014:2 and z-axis is the value of the response of MP factor to a negative one standard deviation shock to fiscal regime factor.

Figure 34: IRF to a Shock to Policy Factors in Full Sample Period: M-F



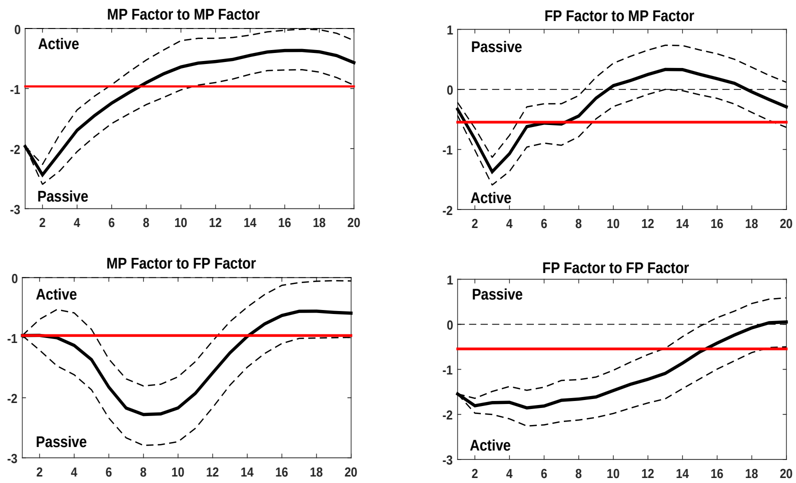
Notes: Figure 34 presents impulse responses to a negative one standard deviation shock to MP and FP regimes for full sample period (1949:2-2014:2). Dotted lines represent 90% confidence intervals. The order of variables is MP factor first, FP factor later. Red dotted lines are estimated thresholds for monetary and fiscal policy rules respectively.

Figure 35: IRF to a Shock to Policy Factors in Full Sample Period: F-M



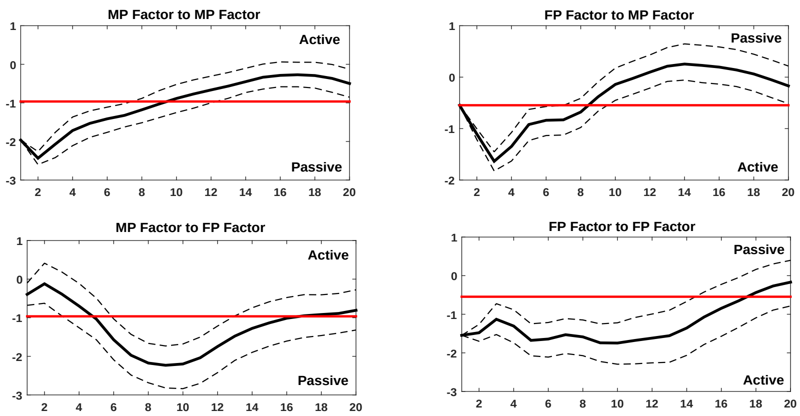
Notes: Figure 35 shows impulse responses to a negative one standard deviation shock to MP and FP regimes for full sample period (1949:2-2014:2). Dotted lines represent 90% confidence intervals. The order of variables is FP factor first, MP factor later. Red dotted lines are estimated thresholds for monetary and fiscal policy rules respectively.

Figure 36: IRF to a Shock to Policy Factors in Sub-Sample Period: M-F



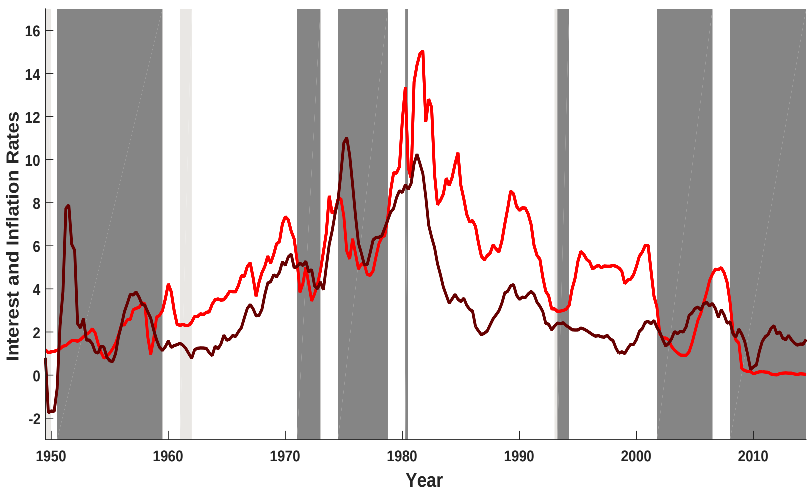
Notes: Figure 36 presents impulse responses to a negative one standard deviation shock to MP and FP regimes for sub-sample period (2000:1-2014:2). Dotted lines represent 90% confidence intervals. The order of variables is MP factor first, FP factor later. Red dotted lines are estimated thresholds for monetary and fiscal policy rules respectively.

Figure 37: IRF to a Shock to Policy Factors in Sub-Sample Period: F-M



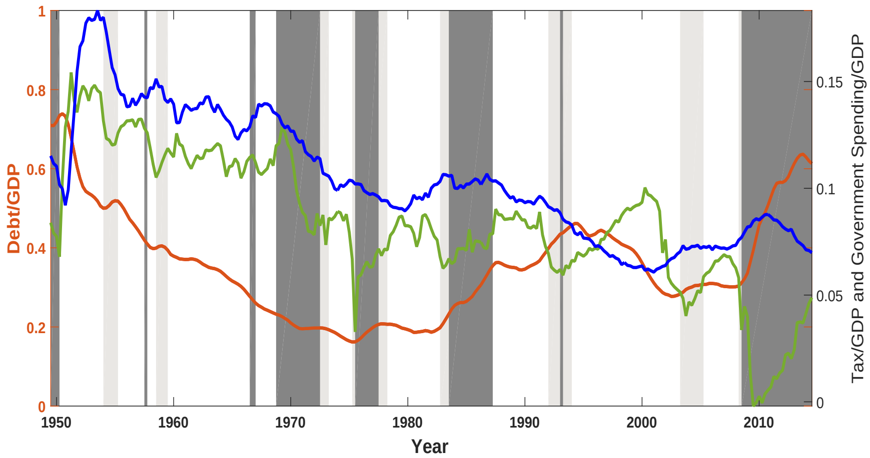
Notes: Figure 37 shows impulse responses to a negative one standard deviation shock to MP and FP regimes for sub-sample period (2000:1-2014:2). Dotted lines represent 90% confidence intervals. The order of variables is MP factor first, FP factor later. Red dotted lines are estimated thresholds for monetary and fiscal policy rules respectively.

Figure 38: Conventional Regime Switching Monetary Policy Model and Estimated State Distribution



Notes: Figure 38 shows the comparison between the estimated state distribution from the endogenous regime switching monetary policy model and that from the conventional markov switching model corresponding to our specification. Red line is T-bill rate, and black line is inflation rate. The light grey shade is the identified passive MP regime only for the endogenous regime switching model and the dark grey shade is the identified passive MP regime for both model. Dark grey shade represents the identified passive MP only for the conventional markov switching model. The endogenous regime switching model identifies a regime based on the monetary regime factor and the estimated threshold, whereas the conventional markov switching model identifies a regime based on the inferred probability.

Figure 39: Conventional Regime Switching Fiscal Policy Model and Estimated State Distribution



Notes: Figure 39 shows the comparison between the estimated state distribution from the endogenous regime switching fiscal policy model and that from the conventional markov switching model corresponding to our specification. Green line represents tax/GDP ratio, red line is government spending/GDP ratio, and orange line is debt/GDP ratio. Light grey shade is the identified active FP regime only for the endogenous regime switching model. Medium grey shade is the identified active FP regime for both models. Dark grey shade represents the identified active FP only for the conventional markov switching model. The endogenous regime switching model identifies a regime based on the fiscal regime factor and the estimated threshold, whereas the conventional markov switching model identifies a regime based on the inferred probability.

Appendix D: Data Description

All series were downloaded from St. Louis's FRED database and cover from 1959:1 to 2013:1. Some series come from the Global insights Basic Economics Database.[53] Some constructed fiscal variables come from NIPA Table 3.2 and debt to GDP ratio is from the Federal Reserve Bank of Dallas' database. All series were seasonally adjusted. Some series in the database were observed only on a monthly basis and quarterly values were computed by averaging the monthly values over the quarter. All variables are transformed to be approximate stationary. The transformation codes are 1: no transformation, 2: first difference, 4: logarithm, 5: first difference of logarithm. An asterisk (*) next to the mnemonic denotes a variable constructed by authors.

Table 10: Data Description

	Mnemonic	T.Code	Description
1	CBI	1	Change in Private Inventories
2	GDPC96	5	Real Gross Domestic Product, 3 Decimal
3	FINSLC96	5	Real Final Sales of Domestic Product, 3 Decimal
4	CIVA	1	Corporate Inventory Valuation Adjustment
5	CP	5	Corporate Profits After Tax
6	CNCF	5	Corporate Net Cash Flow
7	GDPCTPI	5	Gross Domestic Product: Chain-type Price Index
8	FPI	5	Fixed Private Investment
9	GSAVE	5	Gross Saving
10	PRFI	5	Private Residential Fixed Investment
11	CMDEBT	5	HH Sector: Liabilites: HH Credit Mkt. Debt Outstanding
12	INDPRO	5	Industrial Production Index
13	NAPM	1	ISM Manufacturing: PMI Composite Index
14	HCOMPBS	5	Business Sector: Compensation Per Hour
15	HOABS	5	Business Sector: Hours of All Persons
16	RCPHBS	5	Business Sector: Real Compensation Per Hour
17	ULCBS	5	Business Sector: Unit Labor Cost
18	COMPNFB	5	Nonfarm Business Sector: Compensation Per Hour
19	HOANBS	5	Nonfarm Business Sector: Hours of All Persons
20	COMPRNFB	5	Nonfarm Business Sector: Real Compensation Per Hour

[53]Series mnemonic: HHSNTN, PMNO, PMDEL, PMNV, MOCMQ, MSONDQ, DIJA, JSPINDN, JSPNS

23	UEMPLT5	5	Civilians Unemployed - Less Than 5 Weeks
24	UEMP5TO14	5	Civilian Unemployed for 5-14 Weeks
25	UEMP15OV	5	Civilians Unemployed - 15 Weeks & Over
26	UEMP15T26	5	Civilians Unemployed for 15-26 Weeks
27	UEMP27OV	5	Civilians Unemployed for 27 Weeks and Over
28	NDMANEMP	5	All Employees: Nondurable Goods Manufacturing
29	MANEMP	5	Employees on Nonfarm Payrolls: Manufacturing
30	SRVPRD	5	All Employees: Service-Providing Industries
31	USTPU	5	All Employees: Trade, Transportation & Utilities
32	USWTRADE	5	All Employees: Wholesale Trade
33	USTRADE	5	All Employees: Retail Trade
34	USFIRE	5	All Employees: Financial Activities
35	USEHS	5	All Employees: Education & Health Services
36	USPBS	5	All Employees: Professional & Business Services
37	USINFO	5	All Employees: Information Services
38	USSERV	5	All Employees: Other Services
39	USPRIV	5	All Employees: Total Private Industries
40	USGOVT	5	All Employees: Government
41	USLAH	5	All Employees: Leisure & Hospitality
42	AHECONS	5	Average Hourly Earnings: Construction
43	AWOTMAN	1	Average Weekly Hours: Overtime: Manufacturing
44	AWHMAN	1	Average Weekly Hours: Manufacturing
45	AHEMAN	5	Average Hourly Earnings: Manufacturing
46	AHETPI	5	Average Hourly Earnings: Total Private Industries
47	HOUST	4	Housing Starts: Total: New Privately Owned Housing U.S.
48	HOUSTNE	4	Housing Starts in Northeast Census Region
49	HOUSTMW	4	Housing Starts in Midwest Census Region
50	HOUSTS	4	Housing Starts in South Census Region
51	HOUSTW	4	Housing Starts in West Census Region
52	HOUST1F	4	Privately Owned Housing Starts: 1-Unit Structures
53	PERMIT	4	New Private Housing Units Authorized by Building Permit
54	PCEPI	5	PCE: Total (Index 2009=100)
55	PCEPISERV	5	PCE: Services (Index 2009=100)
56	PCEPISNOND	5	PCE: Nondurable Good (Index 2009=100)
57	PCEPIDUR	5	PCE: Durable Good (Index 2009=100)
58	NONREVSL	5	Total Nonrevolving Credit Outstanding, SA, Billions of $
59	USGSEC	5	U.S. Government Securities at All Commercial Banks
60	OTHSEC	5	Other Securities at All Commercial Banks

61	TOTALSL	5	Total Consumer Credit Outstanding
62	BUSLOANS	5	Commercial and Industrial Loans at All Commercial Banks
63	CONSUMER	5	Consumer (Individual) Loans at All Commercial Banks
64	LOANS	5	Total Loans and Leases at Commercial Banks
65	LOANINV	5	Total Loans and Investments at All Commercial Banks
66	REALLN	5	Real Estate Loans at All Commercial Banks
67	AMBSL	5	Board of Governors Monetary Base, Adjusted
68	TOTRESNS	5	Total Reserves of Depository Institutions
69	NFORBRES	1	Net Free or Borrowed Reserves of Depository Institutions
70	M1SL	5	M1 Money Stock
71	CURRSL	5	Currency Component of M1
72	CURRDD	5	Currency Component of M1 Plus Demand Deposits
73	DEMDEPSL	5	Demand Deposits at Commercial Banks
74	TCDSL	5	Total Checkable Deposits
75	TB3MS	1	3-Month Treasury Bill: Secondary Market Rate
76	TB6MS	1	6-Month Treasury Bill: Secondary Market Rate
77	GS1	1	1-Year Treasury Constant Maturity Rate
78	GS3	1	3-Year Treasury Constant Maturity Rate
79	GS5	1	5-Year Treasury Constant Maturity Rate
80	GS10	1	10-Year Treasury Constant Maturity Rate
81	MPRIME	1	Bank Prime Loan Rate
82	AAA	1	Moody's Seasoned Aaa Corporate Bond Yield
83	BAA	1	Moody's Seasoned Baa Corporate Bond Yield
84	sTB3MS	1	TB3MS - FEDFUNDS
85	sTB6MS	1	TB6MS - FEDFUNDS
86	sGS1	1	GS1 - FEDFUNDS
87	sGS3	1	GS3 - FEDFUNDS
88	sGS5	1	GS5 - FEDFUNDS
89	sGS10	1	GS10 - FEDFUNDS
90	sMPRIME	1	MPRIME - FEDFUNDS
91	sAAA	1	AAA - FEDFUNDS
92	sBAA	1	BBB - FEDFUNDS
93	EXSZUS	5	Switzerland / U.S. Foreign Exchange Rate
94	EXJPUS	5	Japan / U.S. Foreign Exchange Rate
95	DJIA	5	Dow Jones Stock Avg-30 Ind Stocks
96	JS&PINDNS	5	S&P Stock Price Index-400 Industrials
97	JS&PNS	5	S&P Stock Price Index-Comp (Common Stocks)
98	PPIACO	5	PPI: All Commodities
99	PPICRM	5	PPI: Crude Materials for Further Processing
100	PPIFCF	5	PPI: Finished Consumer Foods
101	PPIFCG	5	PPI: Finished Consumer Goods
102	PFCGEF	5	PPI: Finished Consumer Goods Excluding Foods
103	PPIFGS	5	PPI: Finished Goods
104	PPICPE	5	PPI: Finished Goods: Capital Equipment
105	PPIENG	5	PPI: Fuels & Related Products & Power
106	PPIIDC	5	PPI: Industrial Commodities

107	PPIITM	5	PPI: Intermediate Materials: Supplies & Components
108	CPIAUCSL	5	CPI For All Urban Consumers: All Items
109	CPIUFDSL	5	CPI for All Urban Consumers: Food
110	CPIENGSL	5	CPI for All Urban Consumers: Energy
111	CPILEGSL	5	CPI for All Urban Consumers: All Items Less Energy
112	CPIULFSL	5	CPI for All Urban Consumers: All Items Less Food
113	CPILFESL	5	CPI for All Urban Consumers: All Items Less Food & Energy
114	OILPRICE	5	Spot Oil Price: West Texas Intermediate
115	PMNO	1	NAPM New Orders Index (Percent)
116	PMDEL	1	NAPM Vendor Deliveries Index (Percent)
117	PMNV	1	NAPM Inventories Index (Percent)
118	MOCMQ	5	New Orders, Consumer Goods & Materials, 1996 Dollars (BCI)
119	MSONDQ	5	New Orders, Nondefence Capital Goods, 1996 Dollars (BCI)
120	HHSNTN	1	U. of Michigan Index of Consumer Expectation
121	TGDPR*	1	Tax-GDP Ratio
122	SPGDPR*	2	Government Spending-GDP Ratio
123	DEBGDPR*	1	Debt-GDP Ratio
124	MILGDPR*	2	Military Spending-GDP Ratio
125	INTDET*	1	Net Interest Payment-Debt Ratio
126	OUTGAP*	1	Output Gap
127	NETINT*	1	Net Interest Payment-Government Outlays Ratio