U.S. Monetary-Fiscal Regime Changes in the Presence of Endogenous Feedback in Policy Rules*

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Abstract

We investigate U.S. monetary and fiscal policy regime interactions in a model, where regimes are determined by latent autoregressive policy factors with endogenous feedback. 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, consistently with existence of a unique equilibrium, though both policies are active and government debt grows rapidly in some periods. We observe relatively strong interactions between monetary and fiscal policy regimes after the recent financial crisis. Finally, 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. See, e.g., 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. Leeper (1991) labels the conventional regime M (active monetary/passive fiscal) and the alternative regime F (passive monetary/active fiscal). 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*. 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. (2016) 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. See also von Jagen et al. (2001) and Muscatelli et al. (2002) for some related work.

However, correlations among policy variables can tell us nothing about interactions between policy regimes. Some recent work explores dynamic interactions between monetary and fiscal *regimes*. 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. They are, though, all based on the conventional regime switching model, which assumes that switching of monetary and fiscal regimes is entirely exogenous. Exogenous regime change is silent about a causal mechanism which connects changes in monetary regime to switches in fiscal regime.

This paper takes an important step toward bringing empirical work on regime change closer to theory, by allowing *endogenous* feedback in switching of monetary and fiscal regimes in our model with 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 autoregressive latent policy factor with endogenous feedback, and regime change is triggered whenever the latent policy regime factor crosses a threshold. Using our model, we estimate 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 examine policy regime interactions using policy regime factors which determine policy regimes explicitly in our policy rules.

Endogenous feedback in 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 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.

Our regime switching 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[1] by the maximum likelihood method, using a slightly modified version of the filter developed by Chang et al. (2017). We find two interpretable policy regimes for monetary and fiscal policy rules (active/passive), between which policy rules fluctuate. Estimates undercover strong evidence of endogenous feedback, rejecting the null of no endogenous feedback 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

[1]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.

in its policy choices.[2]

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, 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 also investigate various aspects of interactions between policy regimes and macroeconomic variables. First, we find 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 via adaptive least absolute shrinkage and selection operator (LASSO). The fiscal variables, tax to GDP ratio and net interest payment to government spending ratio, are most important in explaining the monetary regime factor, and the net interest payment to debt ratio has the largest estimated coefficient for the fiscal regime factor. This result can be regarded as an indirect evidence of policy interactions. Second, we use small-scale structural VAR model to show how non-policy regime factors induce policy regime interactions. Shocks to non-policy regime factors, especially those that embody real activity, generate movements in policy regime factors that are theoretically plausible. Finally, to estimate how key macroeconomic variables affect the policy regime interactions, we conduct counterfactual analysis using the factor-augmented VAR (FAVAR) that Bernanke et al.

[2]King (1995) 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.

(2005) introduced. Changes in policy regime interaction induce dynamic impacts on the key macro variables that accord well with a priori expectations.

The rest of the paper is organized as follows. In Section 2, we introduce our regime switching policy rules with endogenous feedback 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 using endogenous policy regime factors in various aspects. Section 4 links the policy regime factors to macro economy by analyzing their dynamic interactions with the key macroeconomic variables and leading macro factors. Section 5 reports robustness results, including the presence of stochastic volatility and the zero lower bound. Section 6 concludes the paper, and Appendix collects additional figures, results from the additional analyses and data description.

2 Policy Rules with Endogenous Feedback

We use a regime switching model with endogenous feedback as in Chang et al. (2017). In our model, regime switching is determined by an autoregressive latent factor with endogenous feedback. 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 that satisfies

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

where $\mathcal{G}_{t-1}$ is the information available at time $t-1$ to the policy makers, which will be specified more precisely later. We may view the policy disturbance u_t as the part of the policy 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.

The state variable s_t determining the policy regime is specified as

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

with a latent policy factor w_t representing the internal information set used by a policy maker for her policy decision, and ψ 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 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 its 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). A part of the policy disturbance u_{t-1} incurred in the previous period will affect the change in the 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 policy regime. We therefore infer how much exogenous component is left in the policy factor from the degree of endogeneity ρ.

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 $u_t = y_t - x_t' \beta_{s_t}$. The current policy choice β_{s_t} depends on the previous policy disturbance u_{t-1} at time $t-1$ 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, 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 $\mathcal{G}_{t-1}$ includes entire history of policy instrument y, policy target variables x, and state variable s (and therefore policy disturbance u too) 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 β_{s_t} in (3) specifies (1) as a well formulated regression 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 states and policy disturbances. Under the conventional exogenous regime switching model, the policy choice is not affected by past states and policy 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 regime switching policy rules from the existing conventional regime switching policy rules is the presence of endogenous feedback in our regime switching.[3]

In what follows, we specify the regime switching models with endogenous feedback 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.

2.1 Policy Rules with Regime Switching

We consider a simple Taylor (1993) rule type monetary policy which makes the nominal interest rate, i_t, depend only on inflation, π_t:[4]

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

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. $a_j(s_t^m)$, $j = c, \pi$, are state dependent monetary policy parameters and u_t^m represents the monetary policy disturbance. 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.[5]

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, the past monetary policy

[3]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, is not directly comparable to ours, which assumes regimes are determined by some unobserved economic fundamentals. Also, their model is calibrated, not estimated.

[4]There exists significant variation in policy rule specification. According to Rotemberg and Woodford (1999), the 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. Interest rate smoothing and expected inflation are widely considered in empirical literature as in Clarida et al. (2000). 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).

[5]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.

disturbance u_{t-1}^m and the current shock v_t^m to policy factor are assumed to be jointly normal with unit variance and $\mathrm{cov}(u_{t-1}^m, v_t^m) = \rho_m$. 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 other structural shocks and their entire history that may affect monetary policy decision but not measured by the target variable π_t. 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[6] and at the same time, the Fed has reacted to emerging economic states purposefully and intermittently.[7]

Our specification 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. Therefore the degree of endogeneity ρ_m can 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. But the timing of this monetary regime change might not be based on economic status only and possibly be influenced by political aspects.

Our 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. Therefore, 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 fiscal policy.[8] We

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

[7](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.

[8]There are some studies of estimated fiscal rules including Bohn (1998), Taylor (2000), Fatas and Mihov (2001),

specify fiscal policy rule that links the tax revenues τ_t net of transfer payments to government spending purchases g_t and previous debt held by public b_{t-1}. Our fiscal policy specification is given as

$$\tau_t = \beta_c(s_t^f) + \beta_b(s_t^f)b_{t-1} + \beta_g(s_t^f)g_t + \sigma^f u_t^f, \tag{5}$$

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 $j = c, b, g$. We also assume that latent fiscal policy factor w_t^f follows AR(1) dynamics $w_t^f = \alpha_f w_{t-1}^f + v_t^f$. The fiscal policy factor shock v_t^f and previous fiscal policy disturbance u_{t-1}^f are jointly normal with unit variance and $\mathrm{cov}(u_{t-1}^f, v_t^f) = \rho_f$. As in the monetary policy rule specification, we allow for two states in fiscal policy coefficients, and interpret fiscal policy factor w_t^f and endogeneity parameter ρ_f in fiscal policy rule exactly as in our monetary policy rule.

Leeper (1991) defines regimes for monetary policy and fiscal policy depending upon the parameter values in monetary and fiscal policy equations. Monetary policy is defined to be active when it responds strongly to inflation by more than one-to one with $\alpha_\pi > 1$ in monetary policy rule (4), and passive when it responds weakly to inflation with $0 \leq \alpha_\pi < 1$. Similarly, fiscal policy is defined to be passive when it reacts strongly to debt with the coefficient on debt β_b in fiscal policy rule (5) strictly greater than real interest rate reflecting the cost of servicing the debt, and active when it reacts weakly to debt with β_b less than the real interest rate. We will use these definitions to interpret our subsequent empirical findings.

2.2 Data and Estimation Results

We use quarterly U.S. data from 1949:1 to 2014:2. To estimate the monetary policy rule (4), we set π_t to be the inflation rate over contemporaneous and prior three quarters as in Taylor (1993) and obtain inflation each period as log difference of GDP deflator. For the nominal interest rate i_t, we use three-month Treasury bill (T-bill) rate in the secondary market.[9] For the estimation of the fiscal policy rule in (5), we use fiscal variables for the federal government only. We let τ_t be the federal tax receipts net of total federal transfer payments as a share of GDP, and b_t be the market value of gross marketable federal debt held by public as a share of GDP,[10] and g_t be the federal government consumption plus investment expenditures as a share of GDP. Monetary

Auerbach (2003), Cohen and Follette (2005), Ballabriga and Martinez-Mongay (2005), Claeys (2004), Davig (2004) and Favero and Monacelli (2005).

[9] We use T-bill rate instead of federal funds rate (FFR) mainly because FFR is available publicly only from 1954:1. Using T-bill rate allows us to study 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.

[10] In fact, we use the average debt-output ratio over previous four quarters as a measure of b_{t-1}.

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_t, g_t) and Federal Reserve Bank of Dallas, U.S. Economic Data and Analysis (for b_t).

Our regime switching monetary and fiscal policy rules are estimated by the maximum likelihood method using a modified Markov switching filter developed by Chang et al. (2017). Tables 1 reports the maximum likelihood estimates, and Figure 1 presents the extracted monetary and fiscal policy factors w_t^m and w_t^f and estimated policy regimes which are determined by policy regime factors and thresholds.

Table 1: Estimation Results for Endogenous Regime Switching Policy Rules

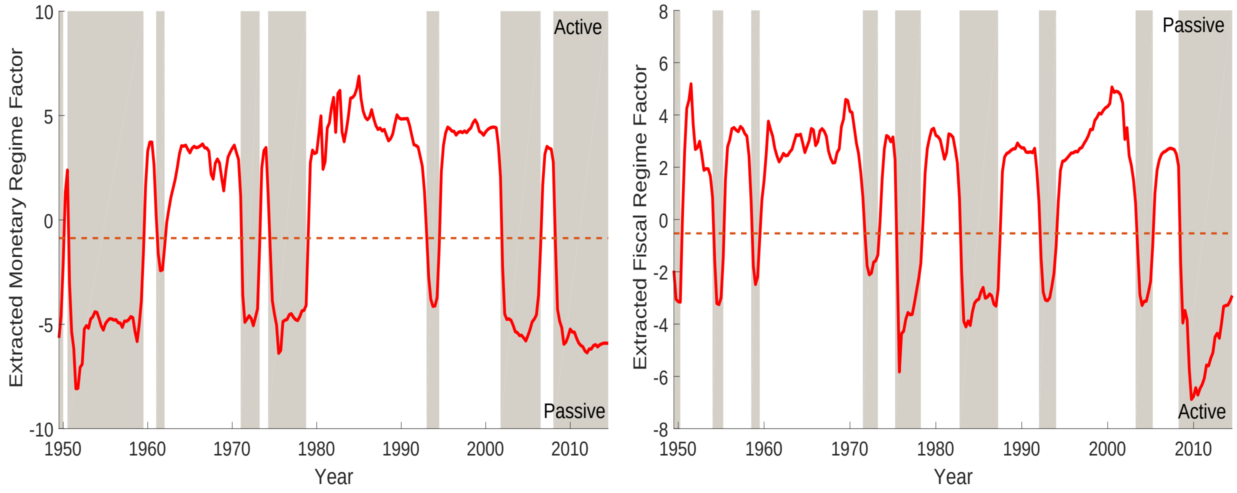
Monetary Policy Rule			Fiscal Policy Rule		
Parameter	Estimate	S.E	Parameter	Estimate	S.E
α_m	0.983	(0.012)	α_f	0.970	(0.020)
ψ_m	-0.871	(1.843)	ψ_f	-0.530	(1.185)
ρ_m	0.999	(0.001)	ρ_f	0.990	(0.025)
$a_c(s_t^m = 0)$	0.459	(0.276)	$\beta_c(s_t^f = 0)$	-0.028	(0.011)
$a_c(s_t^m = 1)$	2.605	(0.255)	$\beta_c(s_t^f = 1)$	0.012	(0.007)
$a_\pi(s_t^m = 0)$	0.660	(0.067)	$\beta_b(s_t^f = 0)$	-0.033	(0.011)
$a_\pi(s_t^m = 1)$	1.039	(0.061)	$\beta_b(s_t^f = 1)$	0.056	(0.012)
			$\beta_g(s_t^f = 0)$	1.027	(0.093)
			$\beta_g(s_t^f = 1)$	0.602	(0.052)
σ^m	1.307	(0.059)	σ^f	0.014	(0.0006)
p-value(LR test for $\rho_m = 0$)	0.000001		p-value(LR test for $\rho_f = 0$)	0.00024	

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 as shown in the left panel of Figure 1. Therefore, we may use the phrase 'active (passive) monetary policy regime' 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[11], showing a strong and clear evidence of the existence of endogeneity in monetary policy regime determination.

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

[11] Here the current shock to the policy instrument would be fully transmitted to the latent monetary policy factor as our estimate of ρ_m is virtually identical to 1.

Figure 1: Extracted Monetary and Fiscal Policy Factors and Estimated Policy Regimes



Notes: The solid and dashed lines on left and right hand side graphs respectively present the extracted policy regime factors and corresponding thresholds from monetary (the left) and fiscal (the right) policy rules. The shaded areas on the left and right panels indicate the passive monetary policy regime and active fiscal policy regime.

a monetary authority would respond more aggressively to inflation in the next period.

The shaded area of Table 1 shows that fiscal policy switches between passive and active by responding more than the 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' as in the right panel of Figure 1. According to our estimation, fiscal policy reacts strongly to government spending and responds weakly to debt in active regime. 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 $\rho_f = 0.99$. 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 6 added in Appendix 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. 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, the values of the maximum log likelihood from the endogenous switching model is larger than that from its exogenous counterpart which has been considered frequently in previous empirical studies. Finally 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 policy regimes. 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 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.

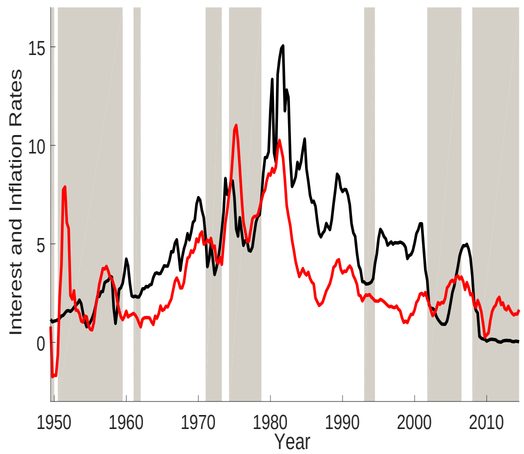
Second, our estimated policy regimes seem quite consistent with narrative accounts of policy history.[12] The left panel of Figure 2 shows the estimated passive monetary policy regimes (shaded areas) and historical data for T-bill and inflation rates. Except for the three brief periods in 1950:1-1950:2, 1959:3-1960:4, 1973:1-1974:2 and a longer period in 1962:1-1970:4, monetary policy was passive until October 1979 when the Fed changed operating procedures and responded to inflation aggressively. After 1980, monetary policy has been mostly active except for the two passive periods immediately after two recessions in 1991 and 2001. Monetary policy continued to weakly respond to inflation even after the official troughs of the downturns with sluggish labor market recoveries. Monetary policy became active when the Fed launched its preemptive strike against inflation in 1994. After the 2007-2008 financial crisis, monetary policy has become passive.

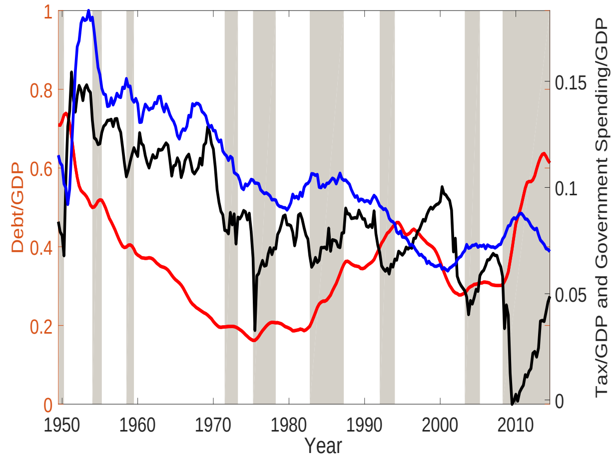
Our estimation results are also broadly consistent with previous empirical findings. At the beginning of our sample until Treasury Accord of March 1951, Federal Reserve policy supported high bond prices by keeping interest rates lower even though consumer price index rose, indicating a passive monetary policy. During the entire 1950s, as the Korean War intensified, monetary policy largely accommodated the financing needs of fiscal policy (Ohanian (1997) and Woodford (2001)). 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 1970s, we find that monetary policy regime was passive with explosive inflation rates as reported in previous empirical findings.

Since 1979, monetary policy was active except for two short periods following the recessions in 1991 and 2001. 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, some governors expressed concern that the Fed was keeping the

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

Figure 2: Historical Data and Estimated Policy Regimes for Monetary and Fiscal Policy Rules





Notes: Black and red lines in the left panel of Figure 2 are T-bill and inflation rates used in estimation of monetary policy rule. The right panel of Figure 2 presents tax/GDP ratio (black), debt/GDP ratio (red) and government spending/GDP ratio (blue) in estimation of fiscal policy rule. The shaded areas represent estimated policy regimes as in Figure 1.

rate low for too long and dissented on the vote to maintain the funds rate at 3 percent (Board of Governors of the Federal Reserve System (1993a)). Also, there are concerns related to negative real interest rates since 2001 and the flood of liquidity in 2003 and 2004 (Unsigned (2005a,b)).

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 based on concerns related to potential inflation pressure.[13] 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.

The right panel of Figure 2 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 policy regime from our endogenously switching fiscal policy rule accords 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 of an income tax cut bill and passed the Income Tax Reduction Act of 1948. From 1950-1953, fiscal policy became passive, as income taxes, and excise taxes were raised and capital taxation were extended to finance Korean War. During the 1960s, fiscal policy became

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

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.

In 1993, fiscal policy switched to being passive with President Clinton's tax hike which is also referred as the Deficit Reduction Act of 1993. Subsequent tax reductions in 2002 and 2003 President Bush made fiscal policy active again.[14] 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

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. (2016)).

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, 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

[14]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). Our estimation results show that active fiscal policy regime is not simply identified by recessions. More interestingly, during economic downturns, 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.

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 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. 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.

3.1 Understanding 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.

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 variables 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. Policy instrument variables, short-term interest rate and tax revenue to GDP ratio are not considered in our analysis for finding the macro-finance variables that have explanatory power for monetary and fiscal policy regime factors respectively.

To effectively select a set of such macro-finance variables 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. A more detailed explanation on our implementation of the adaptive LASSO method is provided in Appendix.

Table 2: Selected Variables for Monetary and Fiscal Policy Regime Factors

Variable Selection for Monetary Factor	Est.Coeff	S.E	Category
6 Month T-bill rate	2.48	0.65	Interest rate
Tax/GDP ratio	1.32	0.29	Fiscal
Bank prime loan rate	0.93	0.57	Interest rate
Extracted fiscal policy factor	0.58	0.24	Fiscal
Net interest payment/ Govt.outlays	0.52	0.16	Fiscal
Average weekly hours: manufacturing	0.50	0.13	Employment and hours
Producer price index: finished goods	-0.07	0.24	Price indexes
Average hourly earnings: manufacturing	-0.66	0.19	Employment and hours
Gross domestic product: price index	-1.66	0.31	Price indexes

Variable Selection for Fiscal Factor	Est.Coeff	S.E	Category
Extracted monetary policy factor	1.21	0.13	Monetary
Housing starts: midwest	0.80	0.15	Housing starts and sales
Average hourly earning: construction	0.63	0.13	Employment and hours
Output gap	0.39	0.18	Real output and income
Civilians unemployed: 15 weeks and over	0.35	0.15	Employment and hours
Consumer loans at all commercial banks	-0.24	0.09	Money and credit
All employees: retail trade	-0.41	0.15	Employment and hours
Employees on nonfarm payrolls: manufacturing	-0.42	0.14	Employment and hours
Total checkable deposits	-0.66	0.11	Employment and hours
Net interest payment/Debt ratio	-0.80	0.14	Monetary
Moody's Baa bond yield-FFR	-0.99	0.15	Interest rate

Table 2 reports selected variables for policy regime factors from adaptive LASSO. The top panel of Table 2 presents the 9 variables from the selected model for the MP regime factor, their estimated coefficients and standard errors. 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 expenditure 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 expenditure 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 gross domestic product price index, producer price index, and variables related with employments such as all employees and average weekly hours, average hourly earnings.

Similarly, the bottom panel of Table 2 presents 11 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 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, variables related with employments such as all employees and average hourly earnings are chosen with relatively larger estimates.

The most important finding from the adaptive LASSO analysis is that the fiscal variables, tax to GDP ratio, net interest payment to government expenditures ratio and extracted fiscal policy factor are selected to be most important variables explaining the monetary regime factor, and the net interest payment to debt ratio and extracted monetary policy factor are chosen to be significant for the fiscal regime factor with a larger estimated coefficient. Our findings can be helpful to understand how we can interpret extracted policy regime factors and also can be regarded as an indirect evidence of policy interactions.

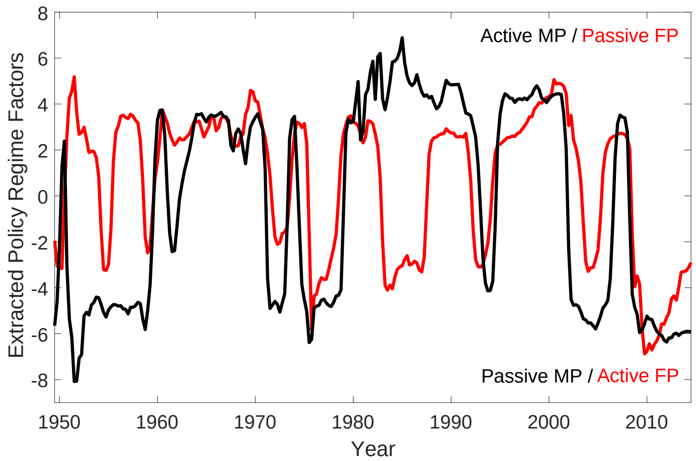
We note that the shrinkage regression analysis we use to select the variables explaining monetary and fiscal regime factors is static and based only on the contemporaneous relationship between the levels of policy regime factors and the variables reflecting the macroeconomic environment. We also study their dynamic interactions which is reported in a later section where we scrutinize the effects of policy regime shocks to various macro variables using a factor augmented VAR. In what follows, we first investigate how the regime factors themselves are interacting and how their interactions have evolved over time.

3.2 Inter-Dynamics of Policy Regime Factors

In this section, we consider a bivariate time varying coefficient VAR (TVC-VAR) model with extracted policy regime factors to investigate the interactions between monetary and fiscal policy authorities. In particular, we examine whether they have interacted to permit monetary and fiscal policies to deliver their primary policy goals. In identifying such policy regime interactions, we follow the notations in Leeper (1991) which provides a simple model in which the price level is jointly determined by monetary and fiscal policy regimes. Specifically, we consider two regimes: active monetary/passive fiscal regime (AM/PF) and passive monetary/active fiscal regime (PM/AF). In AM/PF regime, 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. On the other hand, in PM/AF regime, 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.

Figure 3 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

Figure 3: Extracted Policy Factors from Endogenous Regime Switching Policy Rules



Notes: Black line is the extracted policy factor from monetary policy rule and red line represents the extracted policy factor from fiscal policy rule.

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 0.43. In our context, positive correlation means that, 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 which deliver a unique bounded equilibrium according to macro economic theory.

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 values of monetary and fiscal factors represent a combination of active MP/passive FP. For the sub-sample period, in contrast, average values of monetary and fiscal policy factors signify passive MP/active FP combination given estimated thresholds.[15] 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 on TVC-VAR models. Among many, see Cogley and Sargent (2005), Primiceri (2005) and Gali and Gambetti (2009). 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

[15] The correlation between policy regime factors from monetary and fiscal policies during the sub-sample period is 0.77 which is greater than 0.43 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.

classical kernel methods as in Giraitis et al. (2014, 2015) instead of Bayesian approach.[16]

We consider a TVC-VAR model given by $y_t = A_t y_{t-1} + \eta_t$, where $y_t = (w_t^m, w_t^f)'$, A_t is 2-by-2 matrix of coefficient processes, and $\eta_t = (\eta_t^m, \eta_t^f)'$ is the noise with $E\eta_t\eta_s' = 0, t \neq s, t = 1, 2, \dots T$.[17] The TVC A_t is estimated as

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

with the weights $k_{t,s} = K((t-s)/H_A)$ are given by the kernel function $K(x) \geq 0$, $x \in \mathbb{R}$, and the bandwidth parameter H_A. 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 $\widehat{H}_A$ minimizing $\sum_{t=1}^{T} \left\| y_t - \widehat{A}_{-t} y_{t-1} \right\|^2$ where $\widehat{A}_{-t}$ is an estimate of A_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.[18] 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

[16]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.

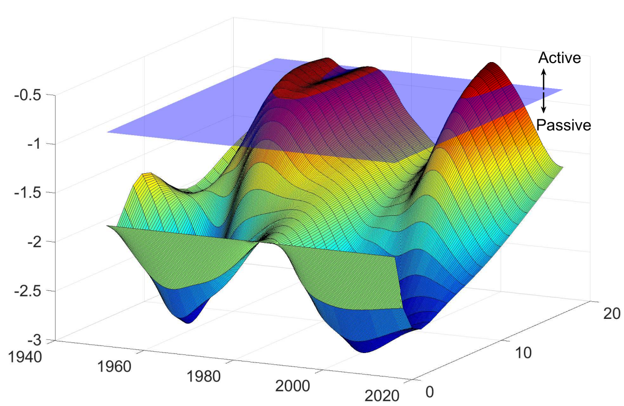
[17]For the actual empirical analysis, we considered extended TVC-VAR models including the intercept term and additional lags. The required extension is straightforward.

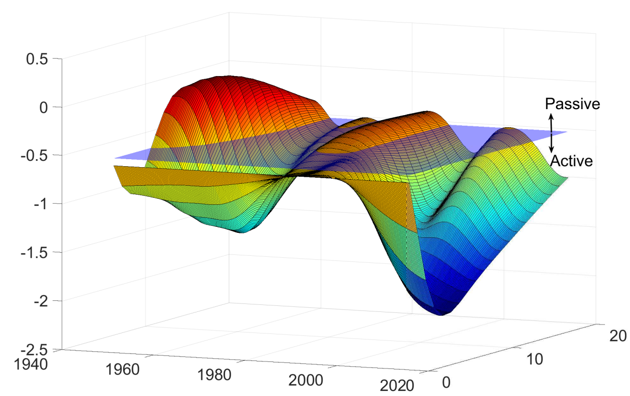
[18]TCV-VAR(1) yields some awkward dynamics. All our results continue to hold in high-order VARs at least qualitatively, though the variability of estimates increases as we include more lags. Therefore, we choose TVC-VAR(2) for parsimony in our specification.

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 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 A_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.[19] Figures 4 and 5 present the responses of the policy regime factors to a negative one standard deviation shock to the monetary and fiscal factors respectively. 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. The transparent blue surface in each figure represents the estimated threshold for each policy rule.

Figure 4: IRFs of Policy Regime Factors to MP Regime Shock in TVC-VAR





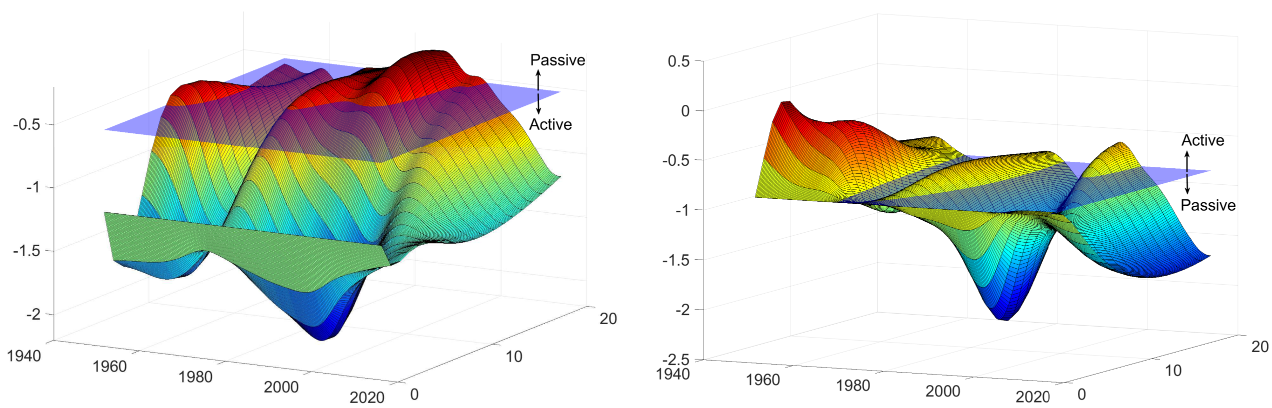
Notes: The left and right panels of Figure 4 respectively show the responses of MP factor and FP factor to negative MP regime shock that makes MP regime passive.

Figure 4 presents the responses of the policy regime factors to a negative shock to the monetary factor which makes monetary policy regime to be more passive. The left hand side of Figure 4 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,

[19]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.

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. The right hand side of Figure 4 shows that fiscal policy becomes active (fiscal factor going under the threshold surface) after the negative shock on the monetary policy regime 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 known to be 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.

Figure 5: IRFs of Policy Regime Factors to FP Regime Shock in TVC-VAR



Notes: The left and right panels of Figure 5 respectively show the responses of FP factor and MP factor to negative FP regime shock that makes FP regime active.

Figure 5 shows the responses of policy regime factors to a negative shock to fiscal factor which makes fiscal policy regime to be more active. The left panel of Figure 5 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, the right panel of Figure 5 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 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.

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.[20]

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.

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 11 added in Appendix shows the impulse responses of policy regime factors to a negative shock to policy regimes on selected years. The first two columns of Figure 11 represent the impulse responses of monetary factor to monetary regime shock and of fiscal factor to monetary regime shock respectively given on the first quarters of 1965, 1982, 2005, 2013. As shown in the first column, 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 active with a large magnitude of

[20]Kliem et al. (2016) 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. (2016). 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).

response and the persistency of shock effect.

The last two columns of Figure 11 show the impulse responses of policy regime factor to a negative shock to the fiscal regime which makes fiscal policy regime active on selected years. The third column represents the impulse responses of fiscal factor to the shock to fiscal regime given on the first quarters of 1955, 1982, 2005, 2013. For 2005 and 2013, effects of fiscal regime shock live longer than other selected years. The fourth column represents the impulse responses of monetary factor to the shock to fiscal regime. Overall, before the 1980s, during most periods, monetary policy regime also becomes active even if fiscal policy regime becomes active. From the early 1980s, monetary policy regime becomes passive when fiscal policy regime becomes active, and the magnitudes of responses increase further after 1990s.

Figure 12 in Appendix presents how effects of policy regime shock evolve over time at the two selected horizons, 5 and 15 quarters after the initial policy regime 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 Linking Policy Regime Factors to Macro Economy

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 analyze responses of policy regime factors to shocks from macro variables using VAR with six selected variables in Section 4.1. We also investigate effects of changes in policy regime factors to some key macroeconomic variables by using factor augmented VAR (FAVAR) in Section 4.2. 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 Key Non-Policy Variables

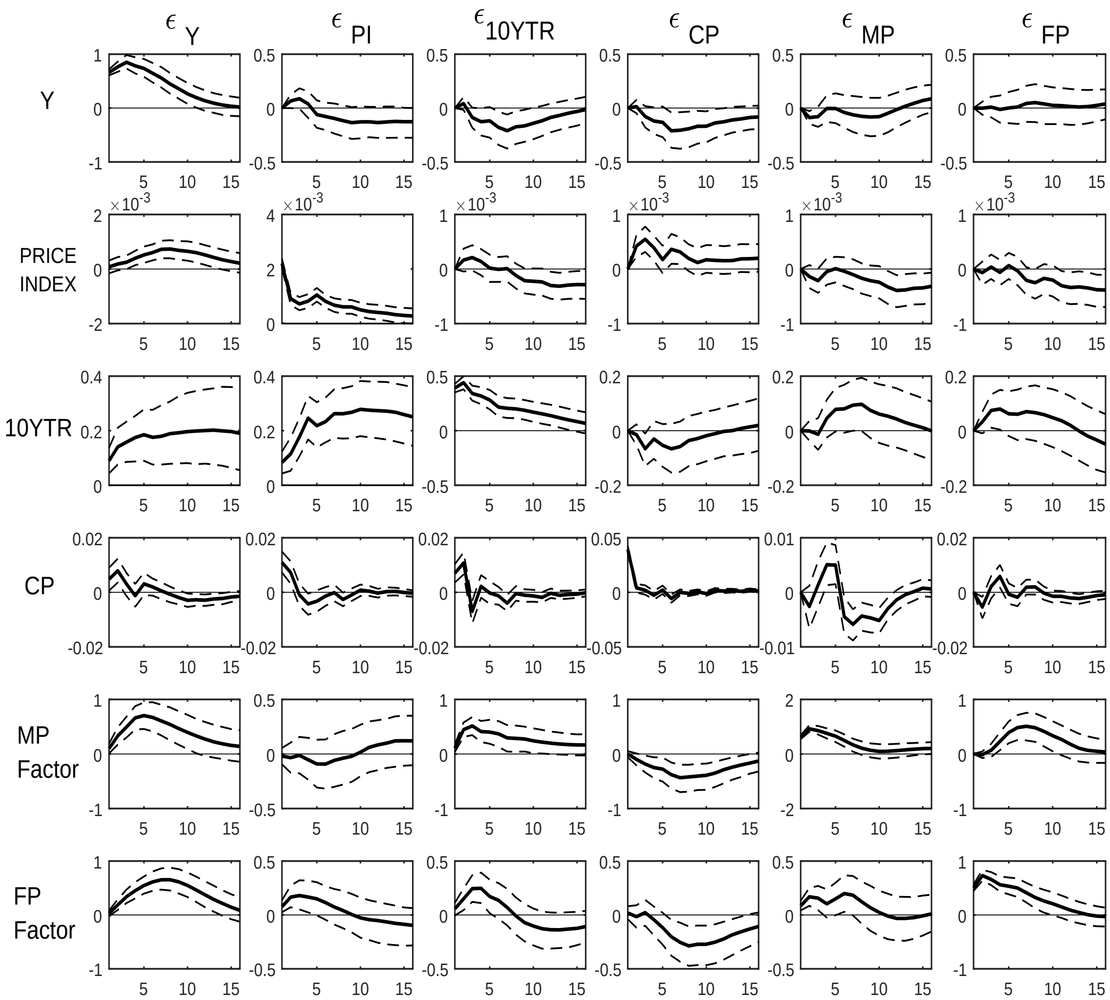
In this section, we consider a small structural model to investigate the effects of non-policy shocks to policy regimes and their interactions.[21] Specifically, the structural form considered in this section is $\sum_{s=0}^{p} A_s y_{t-s} = \epsilon_t$, where y_t is an m by 1 vector of time series and 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, so $\epsilon_t = (\epsilon'_{Nt}, \epsilon'_{Pt})'$, where ϵ_{Nt} is the vector of non-policy disturbances. We estimate an identified VAR including four non-policy variables (output gap, GDP deflator, 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 GDP deflator (PI)-represent the real activity and price level. We consider the long term interest rate, the 10 year T-bill rate (10YTR), 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 price level as predetermined for the rest of the system, reflecting the view that producing and 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

[21] As we emphasized in previous adaptive LASSO analysis, actual monetary and fiscal policy behaviors may be 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 consider several variables based on the previous empirical findings.

logarithmic except the output gap, long term interest rate, and policy regime factors. We estimate with 5 lags.[22]

Figure 6: Impulse Responses of All Variables in VAR Model



Notes: 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 90 % confidence intervals of impulse responses.

Figure 6 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

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

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 policy regime becomes unclear with the wide error band of response and fiscal policy regime becomes passive initially.

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. Monetary policy regime becomes active for a long time and fiscal policy regime becomes passive initially. 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. With mixed effect from the increased price level and decreases output gap, responses of monetary policy regime decreases and fiscal policy regime factor also decreases with some lags 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 a policy regime interaction which delivers a determinate, well-behaved equilibrium in economic theory in terms of the sign and magnitude. The dynamics of policy regime factors from the other non-policy structural shocks may vary, but overall 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 8 quarters and then starts to decrease as the price level decreases. The commodity price index fluctuates from positive to negative. The last column shows that when the fiscal policy regime becomes passive, the response of output gap is unclear with wide error bands and then the price level decreases with some lags. The long term interest rate increases initially and then decreases as the price level decreases. The monetary policy regime becomes active during 16 quarters. Overall, impulse responses of macro variables to policy regime shocks are persistent with a prior expectations.

Table 3 presents the variance decomposition of forecast errors for each of the variables at the 16 quarter horizons. We observe that only 31 % and 34 % of forecast errors of policy factors are attributed to own innovations respectively. Most of the error variances in the MP and FP regime

Table 3: Contributions of Structural Shocks (%) to the Variance of Variables

	Structural Shocks					
Variables	ϵ_Y	ϵ_{PI}	ϵ_{10YTR}	ϵ_{CP}	ϵ_{MP}	ϵ_{FP}
Y	84.7	2.6	4.5	7.0	1.1	0.1
PI	24.5	54.8	3.2	5.9	5.5	6.1
10YTR	25.2	34.3	36.1	0.9	2.0	1.6
CP	6.3	8.2	9.4	63.6	8.4	4.0
MP	29.0	0.6	12.7	15.4	30.5	11.9
FP	47.0	2.0	4.1	10.3	2.4	34.2

factors are attributed to shocks other than own innovations, especially, the shock to the output gap explains 29% and 47% of the error in the forecast of both policy regime factors respectively. 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. In that sense, it is natural that policy regime factors are related to the commodity price index.

4.2 Leading Macro Factors

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. 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.,

$$X_t = \Lambda C_t + e_t = \Lambda^f F_t + \Lambda^w W_t + e_t \tag{6}$$

where W_t represents the monetary and fiscal policy regime factors, F_t the principal components of X_t net of the effect from W_t,[23] 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 extract additional information on general macroeconomic environment from the variables contained in X_t beyond the information already captured by our policy regime factors. The joint dynamics of the common component $C_t = (F_t, W_t)$ are assumed to follow a finite order invertible VAR process as $\Phi(L)C_t = v_t$, which can be written as an infinite order vector MA 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). 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,[24] which does not hold in our case with $N = 127$ and $T = 261$. To account for the uncertainty in the factor estimation, we use the double bootstrapping procedure suggested in Kilian (1998) to compute the confidence intervals for the impulse response functions.

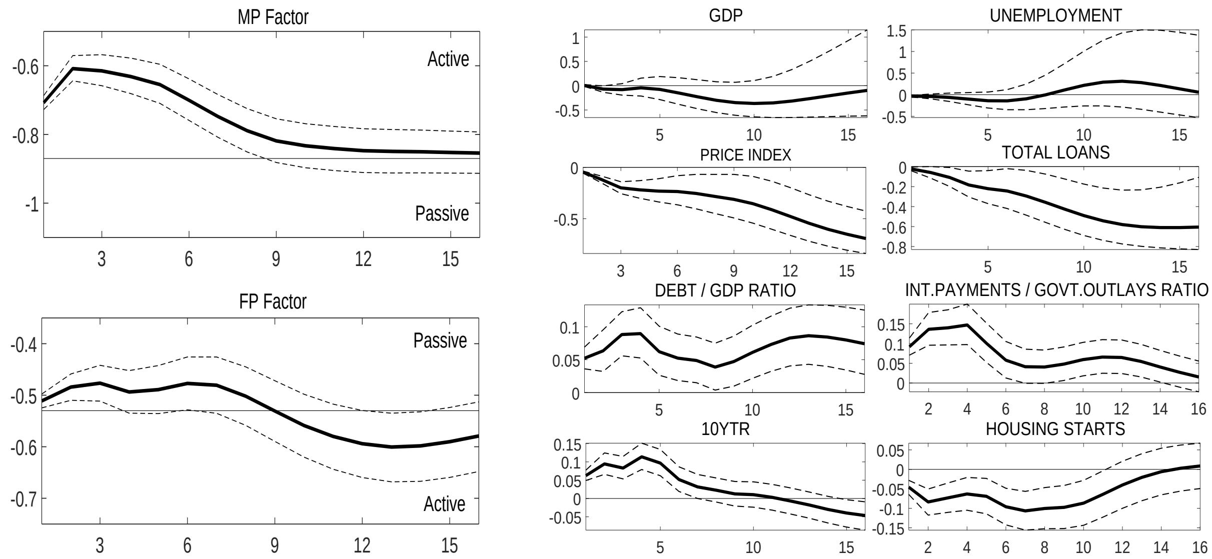
To implement FAVAR in our context, we use the extracted monetary and fiscal policy factors, and the first five leading principal components from 127 macroeconomic variables. For the structural identification, we assume that the monetary regime factor and fiscal regime factor are contemporaneously affected by the five principal components. For the ordering of monetary and fiscal regime factors, we consider two possible cases as in our earlier TVC-VAR analysis, and VAR(5) is considered for the dynamics of the common factors C_t. Our main results are shown in Figures 7-8. 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.[25] The left hand side graph of Figure 7 shows that monetary regime factor increases with a positive one standard deviation shock, i.e., the probability to be active monetary policy regime increases. Consequently,

[23] 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 $X_t - \hat{\Lambda}_0^w W_t$.

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

[25] The bootstrapped impulse responses involve 100,000 iterations.

Figure 7: Responses of Policy Factors and Key Macro Variables to MP Regime Shock in FAVAR



Notes: The left panel of Figure 7 shows the impulse responses of policy factors to MP regime shock that makes monetary policy regime active and the right panel presents the impulse responses of key macro variables to MP regime shock.

fiscal regime factor also increases and the probability to be passive fiscal policy regime increases.[26]

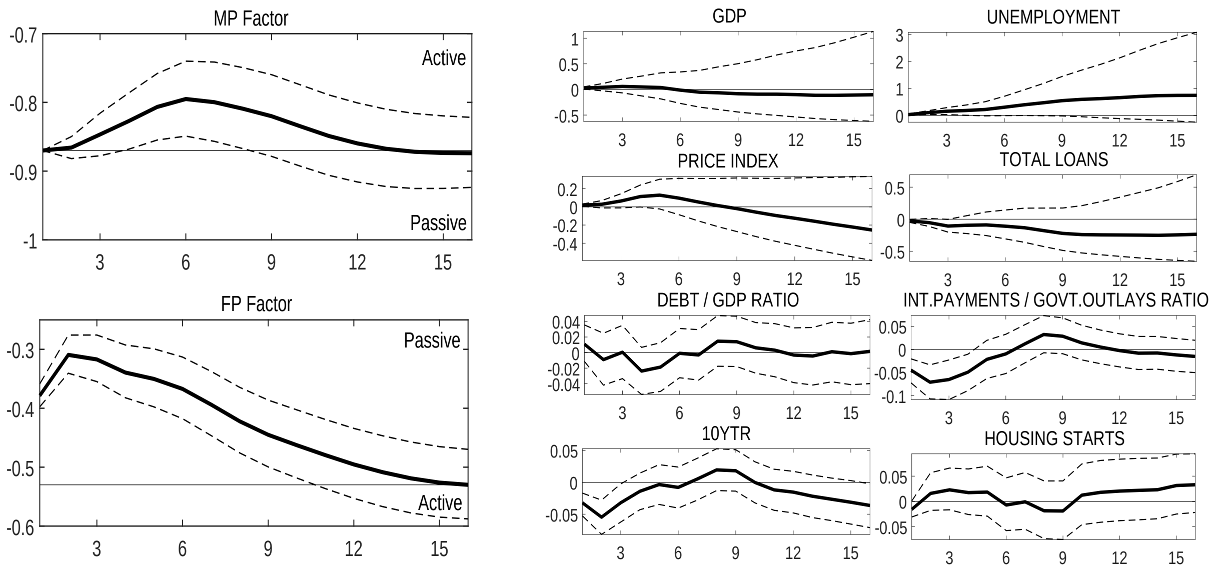
As shown in the right hand side of Figure 7, effects of monetary regime shock decreases GDP and increases unemployment rate with wide error bands including the base line. The price level decreases consistently during 20 quarters.[27] We observe a decrease in total loans from commercial banks also. As the probability of being more active monetary policy regime increases, debt to GDP ratio increases with decreases in GDP. Net interest payment 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 12 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

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

[27]We report the impulse response of GDP deflator as we compute inflation rate using GDP deflator in our estimation of monetary policy rule. We check the impulse response of other measures of the price level (producer and consumer price indexes) and the responses are similar.

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.[28]

Figure 8: Responses of Policy Factors and Key Macro Variables to FP Regime Shock in FAVAR



Notes: The left panel of Figure 8 shows the impulse responses of policy factors to FP regime shock that makes fiscal policy regime passive and the right panel presents the impulse responses of key macro variables to FP regime shock.

The left panel of Figure 8 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 immediately. The right panel of Figure 8 shows that GDP decreases and unemployment increases with wide error bands and some lags after the fiscal policy regime shock. Inflation rate decreases with some lags. Debt to GDP ratio fluctuates with wide error bands and net interest payment to government outlays ratio decreases as the probability of being more passive fiscal policy regime increases. Long-term interest rate starts from a negative value and increases gradually and then decreases. Total loans decreases during 20 quarters and housing starts decreases initially and goes back to zero quickly.

Table 4 reports the variance decomposition results for the same macroeconomic variables considered in the previous Figures. 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.[29] The contribution of the shock to monetary regime factor has a huge effect to all vari-

[28]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.

[29]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

Table 4: Contributions of MP and FP Regime Shocks (%) to the Variance of Variables

Variables	Variance Decomposition		R^2
	MP Regime Shocks	FP Regime Shocks	
w^m	69.6	4.2	1*
w^f	5.7	55.4	1*
GDP	3.7	1.0	0.69
Unemployment	8.5	5.3	0.74
Price Index	13.5	4.1	0.53
Total loans	7.2	6.5	0.70
Debt/GDP ratio	31.7	1.5	0.78
Int.payment/Govt.outlays ratio	40.8	11.4	0.61
10YTR	29.5	8.8	0.86
Housing Starts	10.9	2.3	0.93

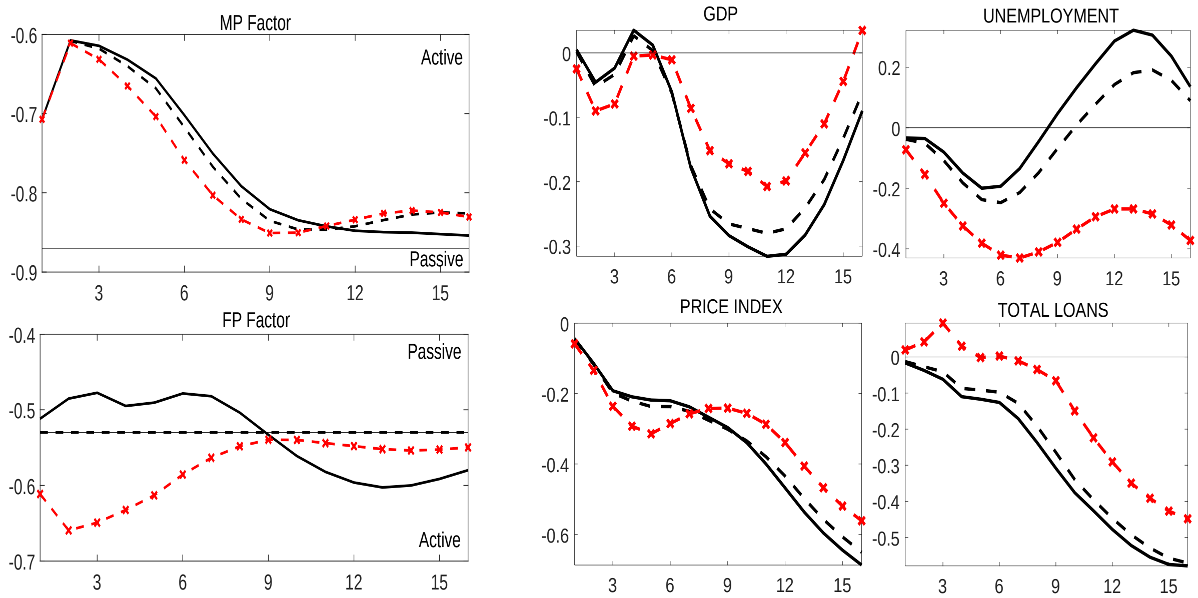
Notes: R^2 refers to the fraction of the variance of the variable explained by the common components. ∗This is by construction.

ables we considered in previous Figures, especially to debt to GDP ratio and net interest payment to government outlays ratio. 32% and 41% of the error in the forecast of debt to GDP ratio and net interest payment to government outlays ratio are attributed to the monetary regime shock. Not only for variables related to a fiscal policy stance, but there is also a non-trivial effect to fiscal regime factor itself. Also, monetary policy regime shock explains 4%, 9% and 14% of GDP, unemployment and price index respectively. The contribution of the shock to fiscal regime has nontrivial but smaller effects to explain the error in the forecast of all variables we considered than those of the monetary policy shock.

We have scrutinized the effects of policy regime shocks to various macro variables. Now we conduct an interesting counter-factual analysis. Consider an 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 interrupts the fiscal policy to respond or induces it to respond in the opposite way to the given monetary policy regime shock that makes monetary policy passive. In Figure 9, 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. Specifically, black dashed lines signify 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. 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 slightly 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

factors. See Bernanke et al. (2005) for details.

Figure 9: Counterfactual IRFs of Policy Factors and Key Macro Variables to MP Regime Shock in FAVAR



opposite way to becoming more active along with the more active monetary policy, GDP decreases much less than the original response. The unemployment decreases drastically, and the price level decreases but less than the original response after 7 quarters. 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 Figure 10, 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. Here, we observe more dramatic changes in GDP and the price level. GDP increases during 16 quarters without decreases as in an original response. The price level also increases continuously unlike the original response.

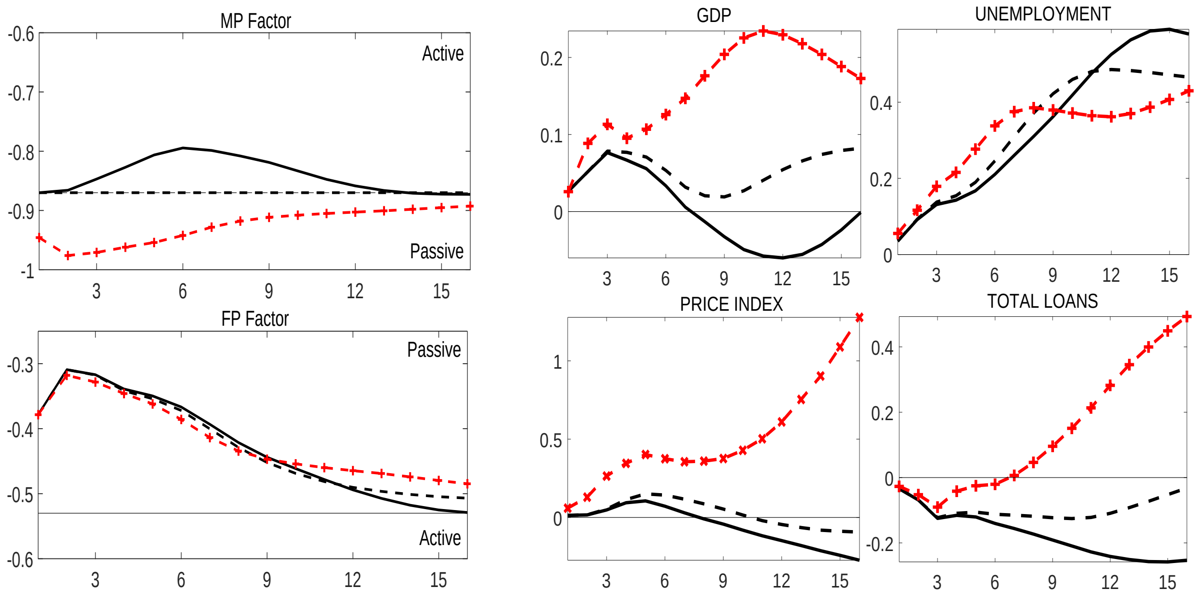
5 Robustness Check

5.1 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.[30] 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.

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

Figure 10: Counterfactual IRFs of Policy Factors and Key Macro Variables to FP Regime Shock in FAVAR



To explain how we deal with the presence of a general form of stochastic volatility, we write our regime switching model (1) extended to allow for the presence of stochastic volatility generically as

$$u_t = \sigma_t \varepsilon_t, \tag{7}$$

where σ_t is a general time varying and stochastic volatility, and $\varepsilon_t \sim \text{iid}\mathbb{N}(0,1)$ 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 presence of stochastic volatility in our MLE. Note that, if ε_t is observed, σ_t^2 can be estimated from $u_t^2 = \sigma_t^2 \varepsilon_t^2 = \sigma_t^2 + \sigma_t^2(\varepsilon_t^2 - 1)$, 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

$$\hat{u}_t = y_t - x_t' \hat{\beta}_{s_t},$$

where $\hat{\beta}_{s_t}$ is the estimate based on our model with a constant volatility, and use $\hat{u}_t^2$ to estimate σ_t^2 using the HP filter with an appropriately chosen smoothing parameter.[31] Subsequently, in the

[31]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

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

second step, we estimate the model

$$y_t^* = x_t^{*\prime} \hat{\beta}_{s_t} + u_t^*,$$

where y_t^* and x_t^* are volatility adjusted y_t and x_t, 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 13 in Appendix 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.

Table 5: Estimation Results for Volatility Adjusted Endogenous Regime Switching Policy Models

Monetary Policy Rule			Fiscal Policy Rule		
Parameter	Estimate	S.E	Parameter	Estimate	S.E
α_m	0.989	(0.006)	α_f	0.960	(0.021)
ψ_m	-0.848	(2.436)	ψ_f	-1.032	(0.976)
ρ_m	0.993	(0.060)	ρ_f	0.972	(0.038)
$a_c(s_t^m = 0)$	0.615	(0.141)	$\beta_c(s_t^f = 0)$	-0.021	(0.004)
$a_c(s_t^m = 1)$	2.133	(0.134)	$\beta_c(s_t^f = 1)$	0.008	(0.003)
$a_\pi(s_t^m = 0)$	0.649	(0.045)	$\beta_b(s_t^f = 0)$	-0.017	(0.007)
$a_\pi(s_t^m = 1)$	1.067	(0.051)	$\beta_b(s_t^f = 1)$	0.048	(0.007)
			$\beta_g(s_t^f = 0)$	0.960	(0.035)
			$\beta_g(s_t^f = 1)$	0.658	(0.025)

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 5. 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 by as much as 50%.[32]

The reader is referred to Chang, Park and Yeo (2016) for a more detailed discussion of this approach to nonparametrically estimate the conditional mean of a given time series.

[32]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.

5.2 Zero Lower Bound

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 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 (2016) 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 (2016) 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 14 added in Appendix 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 becomes smaller than the original factor since 2010:1. 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.[33] 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.

Figure 15 in Appendix presents 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.[34] Again we observe similar patterns of time varying policy interactions in terms

[33]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."

[34]We follow the same specification for TVC-VAR estimation considered in Section 3.

of both magnitudes and signs to those obtained from our earlier TVC-VAR analysis implemented with the original monetary factor based on i_t.

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. (2017) 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

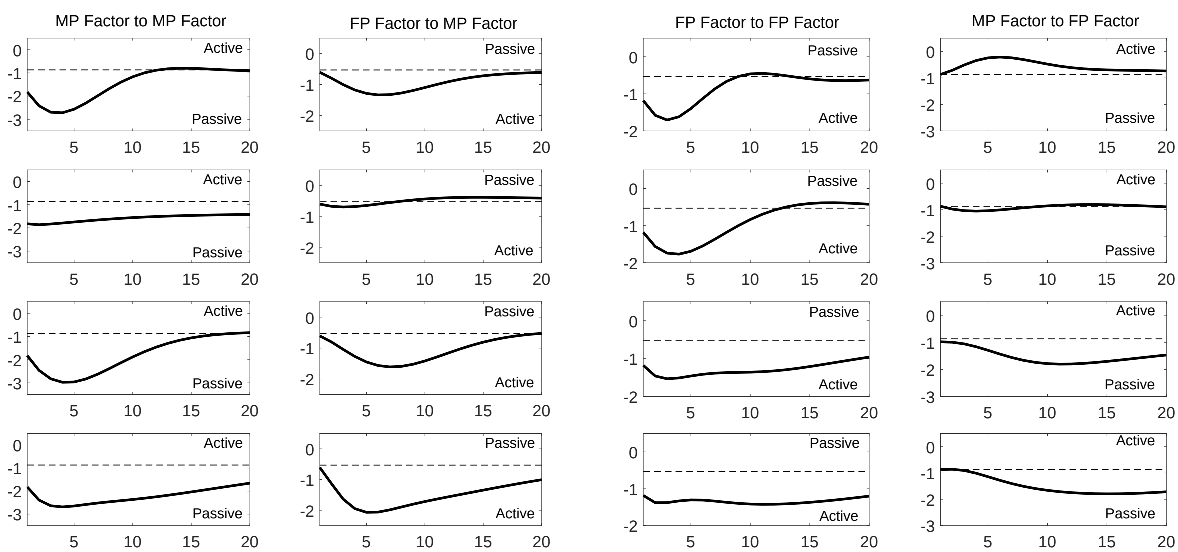
Appendix A: Additional Tables and Figures

Table 6: Implied Averages of Variables Conditional on Regime

Regime	T-bill rate	Inflation rate	Tax/GDP	Debt/GDP	Govt.Spending/GDP
Active	6.11	3.39	0.06	0.38	0.10
Passive	2.43	3.01	0.10	0.33	0.11

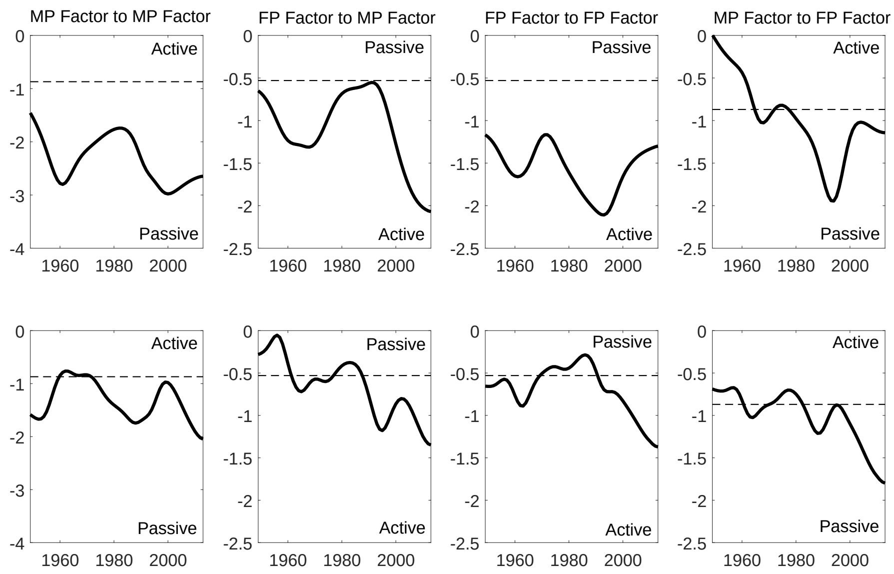
Notes: Table 6 reports the implied averages of variables used in estimations of MP and FP rules conditional on regime. Average inflation, debt/GDP and government spending ratios are calculated from actual data conditional on regime, and implied averages of interest rate and tax/GDP ratio are calculated by plugging those averaged variables by regime and regime dependent intercept terms into the policy rules.

Figure 11: IRFs of Policy Regime Shocks on Selected Years



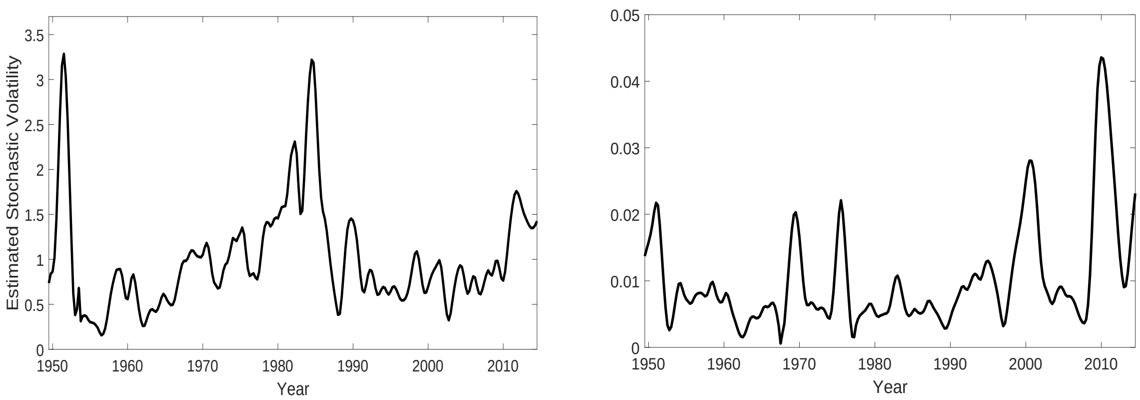
Notes: The four columns present IRFs of MP factor to MP regime shock, IRFs of FP factor to MP regime shock, IRFs of of FP factor to FP regime shock and IRFs of MP factor to FP regime shock from left to right. Dotted straight line are estimated thresholds for monetary policy (-0.87) or fiscal policy (-0.54) respectively. 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 policy regimes. Each row shows the impulse response of MP or FP regime shock in different years. For the first two columns, considered years are (the first quarter of) 1965, 1982, 2005, 2013 from top to bottom rows. For the last two columns, (the first quarter of) 1955, 1982, 2005, 2013 are considered.

Figure 12: IRFs of Policy Regime Shocks on Selected Horizons



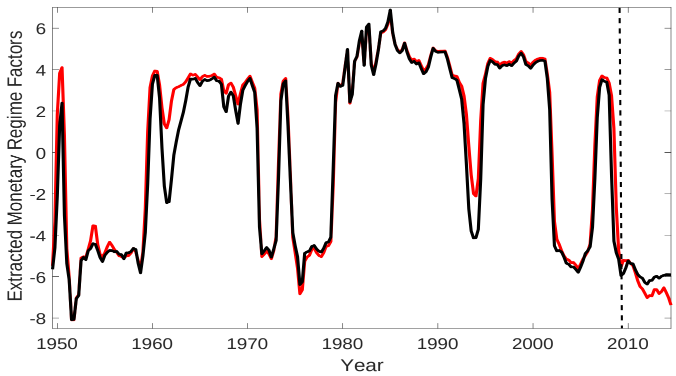
Notes: The four columns represent IRFs of MP factor to MP regime shock, IRFs of FP factor to MP regime shock, IRFs of FP factor to FP regime shock and IRFs of MP factor to FP regime shock from left to right. Dotted straight lines are estimated threshold levels of the responding policy factors. The x-axis 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.

Figure 13: Estimated Stochastic Volatility for Policy Rules



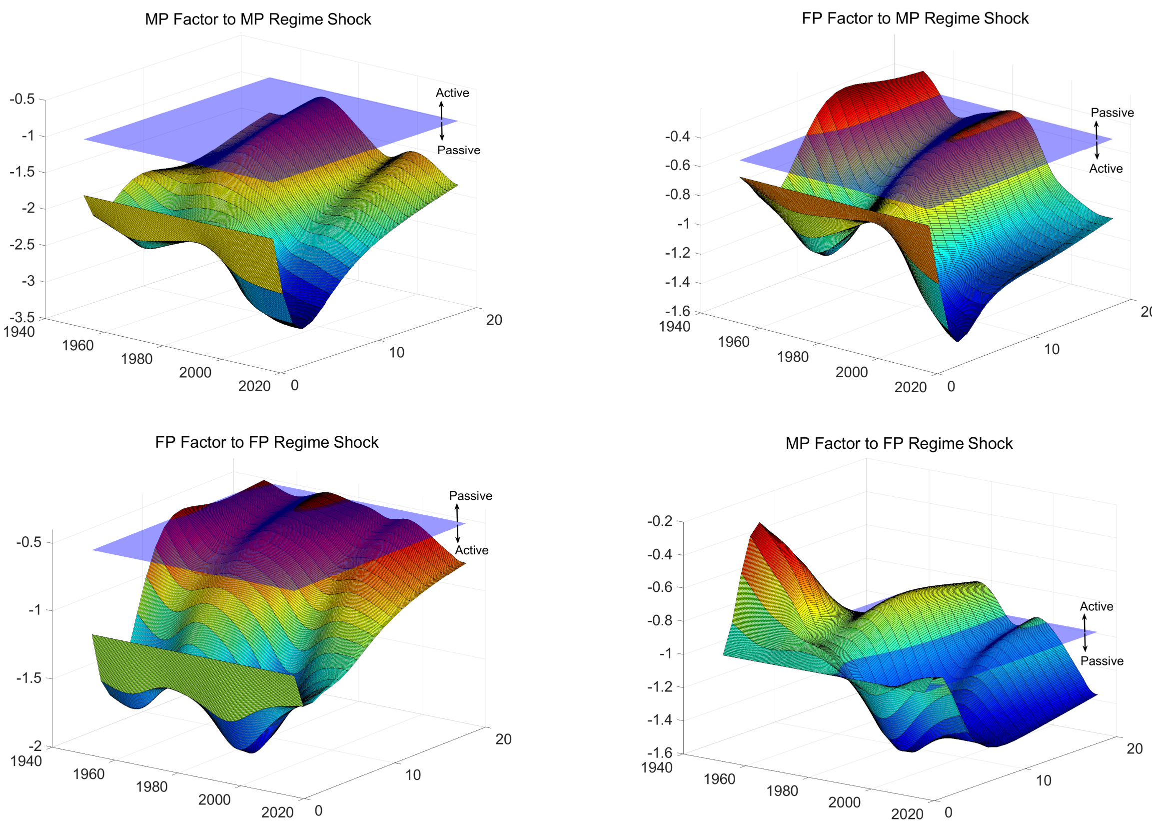
Notes: Figure 13 presents the estimated stochastic volatility for the monetary (the left) and fiscal (the right) policy rules. The stochastic volatility is estimated using a two-step approach and the HP filter with an appropriately chosen smoothing parameter.

Figure 14: 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 (2016). 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 15: IRFs of Policy Factors to Policy Regime Shocks in TVC-VAR with Shadow Rate



Notes: Monetary regime factor is re-estimated using a new policy rate (i_t^*). Blue transparent surfaces represent the estimated thresholds for monetary and fiscal policy rules. 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 policy factors to a negative one standard deviation shock to monetary or fiscal regime factor respectively.

Appendix B: 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 policy regimes. 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 policy regime, 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 policy regimes once filtered or smoothed probabilities are far from 0.5. Figure 16 presents comparisons between the estimated policy regimes 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 policy regimes from endogenous regime switching and conventional regime switching models are overlapped mainly with minor differences.

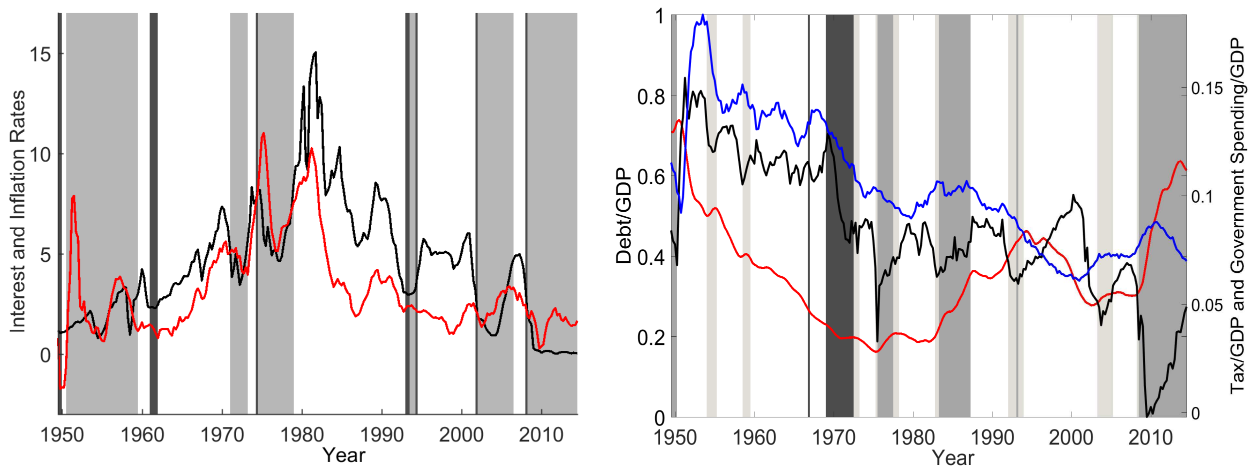
The estimated policy regimes for the fiscal policy, however, shows more differences between endogenous regime switching and conventional regime switching estimations. As shown in the right hand side of Figure 16, the conventional regime switching model with our specification fails to capture some important 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.[35]

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 policy regimes 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 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

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

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.

Figure 16: Conventional Regime Switching Policy Models and Estimated Policy Regimes



Notes: Figure 16 presents the comparison between the estimated policy regimes from the endogenous regime switching monetary and fiscal policy models and that from the conventional markov switching models corresponding to our specification. For the left panel of Figure 16, the light grey shade is the identified passive MP regime only for the endogenous regime switching model and the medium 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. In the right panel of Figure 16, 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 policy regime factor and the estimated threshold, whereas the conventional markov switching model identifies a regime based on the inferred probability.

Appendix C: Fixed Coefficient VARs for Subsamples

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.[36] 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. Here our results from VAR analysis are from the former identification case. 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.[37]

Based on the estimated VAR(8), we analyze the impulse responses. For each policy, we add one negative standard deviation shock from the estimated thresholds.[38] 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 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. The left panel of Figure 17 shows 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

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

[37] The correlation between extracted monetary and fiscal regime factors during the subsample period is 0.77 which is greater than 0.43 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.

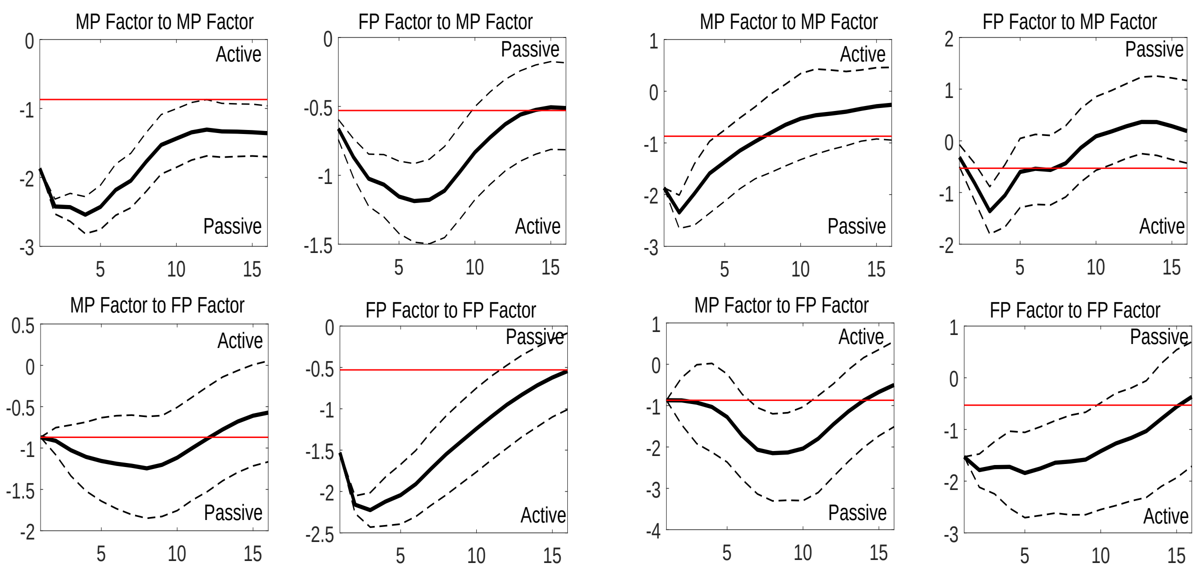
[38] Our impulse response function starts from estimated thresholds for a convenient description of the direction and magnitude of responses.

does not Granger cause monetary policy factor.

The right panel of Figure 17 presents 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 responds weakly to a change in fiscal policy regime in the full sample period, whereas in the subsample period, monetary policy regime responds strongly to a change in fiscal policy regime with the large response and narrow error band. Overall, the policy interaction between MP and FP tends to be stronger and clearer during the subsample period.

Figure 17: IRFs of Policy Factors to Policy Regime Shocks in Full and Sub-Sample Periods



Notes: Figure 17 presents impulse responses to a negative one standard deviation shock to MP and FP regimes for full (the left) and sub-sample (the right) period (1949:2-2014:2). Dotted lines represent 90% confidence intervals. The order of variables is MP factor first, FP factor later. Red lines are estimated thresholds for monetary and fiscal policy rules.

Appendix D: Adaptive LASSO Method

Zou (2006) introduces the adaptive LASSO method 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. Basically the adaptive LASSO 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[39]

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

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) given by $BIC(\lambda) = \| y - X\beta(\lambda) \|^2 + \log(n)\sigma_\epsilon^2 df(\lambda)$, where n is the number of observations, $df(\lambda)$ the degree of freedom given by the number of non-zero coefficients, and σ_ϵ^2 represents the residual variance of a ridge regression when its penalty term goes zero. Since our goal is to pin down only those essential variables, we use BIC which is known to choose a more 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.

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_L where $L = \{i : \beta_i \neq 0\}$, 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).

[39] 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.

Appendix E: Data Description

All series were downloaded from St. Louis's FRED database and cover from 1959:1 to 2014:2. Some series come from the Global insights Basic Economics Database.[40] 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 7: 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
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

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

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	sTB3MS	1	TB3MS - FEDFUNDS
84	sTB6MS	1	TB6MS - FEDFUNDS
85	sGS1	1	GS1 - FEDFUNDS
86	sGS3	1	GS3 - FEDFUNDS
87	sGS5	1	GS5 - FEDFUNDS
88	sGS10	1	GS10 - FEDFUNDS
89	sMPRIME	1	MPRIME - FEDFUNDS
90	sAAA	1	AAA - FEDFUNDS
91	sBAA	1	BBB - FEDFUNDS
92	EXSZUS	5	Switzerland / U.S. Foreign Exchange Rate
93	EXJPUS	5	Japan / U.S. Foreign Exchange Rate
94	DJIA	5	Dow Jones Stock Avg-30 Ind Stocks
95	JS&PINDNS	5	S&P Stock Price Index-400 Industrials
96	JS&PNS	5	S&P Stock Price Index-Comp (Common Stocks)
97	PPIACO	5	PPI: All Commodities
98	PPICRM	5	PPI: Crude Materials for Further Processing
99	PPIFCF	5	PPI: Finished Consumer Foods
100	PPIFCG	5	PPI: Finished Consumer Goods
101	PFCGEF	5	PPI: Finished Consumer Goods Excluding Foods
102	PPIFGS	5	PPI: Finished Goods
103	PPICPE	5	PPI: Finished Goods: Capital Equipment
104	PPIENG	5	PPI: Fuels & Related Products & Power
105	PPIIDC	5	PPI: Industrial Commodities
106	PPIITM	5	PPI: Intermediate Materials: Supplies & Components
107	CPIAUCSL	5	CPI For All Urban Consumers: All Items
108	CPIUFDSL	5	CPI for All Urban Consumers: Food
119	CPIENGSL	5	CPI for All Urban Consumers: Energy
110	CPILEGSL	5	CPI for All Urban Consumers: All Items Less Energy
111	CPIULFSL	5	CPI for All Urban Consumers: All Items Less Food
112	CPILFESL	5	CPI for All Urban Consumers: All Items Less Food & Energy
113	OILPRICE	5	Spot Oil Price: West Texas Intermediate
114	COMINDX	5	CRB BLS Spot Index
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