U.S. Monetary and Fiscal Policy Regime Changes and Their Interactions*

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Abstract

We investigate U.S. monetary and fiscal policy interactions in a regime switching model of monetary and fiscal policy rules. Policy regimes are determined by a bivariate latent policy regime factor composed of monetary and fiscal policy factors, each determining the respective policy stance. Both policy factors receive feedback from past policy disturbances and interact contemporaneously and dynamically to determine policy regimes jointly. We observe strong feedback and dynamic interaction between monetary and fiscal authorities. A most salient feature of these interactions is that past monetary policy disturbance strongly influences both monetary and fiscal policy stances, and monetary authority responds to the past fiscal policy stance. We find that the U.S. monetary and fiscal policies have been interacting consistently with the existence of a unique equilibrium: shocks that switch one policy from active to passive stance tend to induce the other policy to switch from passive to active.

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1 Introduction

The recent financial crisis and Great Recession have generated growing interest in the monetary and fiscal policy interactions and their joint effects on the macroeconomy. Theoretical analyses of policy interaction focus on how monetary and fiscal policies can jointly accomplish the tasks of price level determination and debt stabilization.[1] There are two distinct, but equally plausible, policy regimes that permit monetary and fiscal policies to accomplish their primary tasks, inflation/price determination and government debt stabilization. The conventional policy regime has a central bank that stabilizes inflation by systematically raising nominal interest rates more than one-for-one with inflation while a 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 current and future primary surpluses. Monetary policy passively permits a 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 policy regimes are consistent with the existence of a determinate bounded rational expectations equilibrium.

Some recent works explore regime switching policy rules to investigate how monetary and fiscal policies have interacted historically.[2] Regime switching models have been used to describe changes in policy behaviors by imposing regime switching in a policy function that maps the economic state to choices of policy variables in a univariate, vector autoregression (VAR) or dynamic stochastic general equilibrium (DSGE) setup. Most previous specifications on regime changes in policy rules, however, assume that policy behaviors change exogenously and consequently are unable to explain why regime changes may occur and how regime changes in one policy affect those of the other. This is unsatisfactory since monetary and fiscal policies are perceived to be purposeful and may influence each other. The use of conventional, exogenous regime switching models therefore limits the inferences we may draw about policy interactions. In this paper, we propose an alternative regime switching model for monetary and fiscal policy rules where changes in monetary and fiscal policy stances are allowed to interact with each other and receive feedback from previous policy actions.

In our study, we assume that monetary policy follows a Taylor-type rule that makes the nominal interest rate depend on the lagged interest rate, inflation, output gap and monetary disturbance, and that fiscal policy adjusts tax revenues in response to government purchases, real market value of outstanding government debt, output gap and fiscal disturbance with a smoothing component. Choice of policy instrument in each policy rule depends on smoothing behavior, systematic re-

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[1] See, e.g., Sargent and Wallace (1981), Wallace (1981), Aiyagari and Gertler (1985), Sims (1988), and Leeper (1991)

[2] For example, Favero and Monacelli (2005), Davig and Leeper (2006b), Chung et al. (2007), Bianchi (2012), Bianchi and Ilut (2017), and Gonzalez-Astudillo (2018)

sponses to policy target variables as well as on policy disturbance that reflects how policy choice reacts to non-target information. We consider a bivariate model of the monetary and fiscal policy rules with a systematic regime switching mechanism where policy regimes are determined by a bivariate latent policy regime factor composed of monetary and fiscal policy factors determining monetary and fiscal policy stances, respectively. Specifically, policy parameters in each policy rule are specified as functions of the respective policy factor, which determines policy stance. Monetary policy factor determines monetary policy stance as active if it is above a threshold and passive otherwise. Similarly, fiscal policy stance is determined by fiscal policy factor either as passive or active depending on whether fiscal policy factor is above or below a threshold. We may therefore naturally interpret policy factors as unobserved internal information sets that policy authorities use to determine their policy stances.

Two policy factors jointly determine policy regimes. There are four possible policy combinations, which we call regimes - two stable regimes (one with active monetary policy stance and passive fiscal policy stance, and the other with passive money and active fiscal policy stances, termed respectively as regime M and regime F in Leeper (1991)), one indeterminate regime (with passive money and passive fiscal policy stances), and one explosive regime (with active money and active fiscal policy stances). The bivariate latent policy regime factor is assumed to evolve as a vector autoregressive process to explicitly allow its components, monetary and fiscal policy factors, to interact dynamically and contemporaneously. A most interesting and novel contribution of our study lies in our model's ability to elicit the interaction between the monetary and fiscal policy factors that jointly determine policy regimes. For example, our analysis can explicitly show how monetary authority's choice of its rule may influence fiscal authority's choice of its rule, and vice versa, which is particularly relevant since many believe that central banks take into account the stance of fiscal policy in its policy choices.[3]

Policy factors are also allowed to receive feedback from past policy disturbances which may represent policy makers' considerations beyond what is already reflected in target variables. The innovations that drive policy factors in the current period are correlated with the past policy disturbances, and this correlation is what produces the dynamic feedback effects. Our bivariate system of policy rules features two types of dynamic feedback, self-feedback and cross-feedback. Self-feedback occurs within each policy rule, channeling the information from its own past policy disturbance to current policy factor. For example, when monetary policy sets the nominal interest rate above the level implied by target variables, we have a positive monetary policy disturbance, which predicts future changes in the monetary policy factor and consequently monetary policy stance. Cross-feedback, on the other hand, occurs across two policy rules, either from past monetary policy disturbance to current fiscal policy factor, or from past fiscal policy disturbance to current monetary policy factor. The cross-feedback allows us to analyze whether and how a change in

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[3] 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.

one policy's stance may lead to a change in the stance of the other policy. The dynamic feedback establishes an effective channel through which the additional information on the economy relevant for policy regime changes is carried on to the policy factors determining the current policy stances and policy regime. Therefore, the feedback makes the switches of policy stances and regimes consistent with the common perspective on purposeful policy behaviors. For this reason, we view the feedback from policy disturbances to policy factors as *endogenous feedback channels* to policy regime changes. We may easily measure the feedback effects and use them to quantify how the past policy disturbances influence current policy making and regime determination.

Policy regime changes are therefore driven by the endogenous feedback channels together with the *dynamic policy interaction* through interdependence of two policy factors over time, and contemporaneous policy interactions arising from correlation between two policy factors. Since policy factors are affected by the past policy disturbances, we first purge out their effects from the policy factors to measure pure policy interactions taking place in the current period. We call this new measure of policy interaction net of the feedback effect as *contemporaneous policy coordination*. Dynamic interaction and contemporaneous policy coordination among two policy factors measure the degree of monetary and fiscal policy interactions. These measures crucially relevant for understanding the nature of the changes in policy stances and origins of policy interactions are new, and they become available due to our systematic regime switching mechanism. In the next section, we define precisely these three critical components of monetary and fiscal policy regime changes, the endogenous feedback channels, dynamic policy interaction and contemporaneous policy coordination, and provide economic and econometric interpretations of these measures.

We estimate our bivariate system of regime switching U.S. monetary and fiscal policy rules by the maximum likelihood method using a modified version of the filter developed by Chang et al. (2020) for regime switching models with multiple regime factors. We identify and estimate individual policy stances and measure the impacts of endogenous feedback channels, dynamic policy interactions and contemporaneous policy coordination. We find two interpretable policy stances (active/passive) in monetary and fiscal policy rules, between which the policy rules fluctuate. Estimates provide strong evidence of both self-feedback and cross-feedback channels. We find that the current monetary policy disturbance has a strong influence on the switching of next period monetary policy stance through self-feedback and the change in fiscal policy stance through cross-feedback. However, fiscal policy disturbance shows weaker feedback effects on the switching of policy stances for both monetary and fiscal policies. Our findings also show the existence of strong interactions between two policy authorities. We find that a change in fiscal authority's policy stance leads to switching in monetary policy stance, which is clearly shown through the dynamic interactions of the two policy factors. We also find strong evidence of contemporaneous policy coordination among two policy factors. We may therefore draw much detailed inference on policy regime changes by properly taking into account these important ingredients of policy regime changes.

Based on our estimates, we scrutinize the impacts of endogenous feedback, dynamic interaction and contemporaneous policy coordination on policy interaction in both impulse response and frequency domain analyses. For an impulse response analysis, we decompose monetary and fiscal policy disturbances and factor innovations into four orthogonal shocks labeled monetary and fiscal policy shocks and factor shocks. We find that the monetary policy shock and the fiscal factor shock are the most prominent shocks in driving both policy factors' responses. Three crucial channels characterize the chain of shock propagation in our fitted model. We find the main channels in the short-run shock propagation to be the feedback from both policy shocks to the fiscal policy factor. Another short-run channel we identify is the contemporaneous correlation between policy factor innovations induced by fiscal factor shock. In the longer run, the primary channel of the shock propagation is the monetary policy responses to past fiscal policy stances. By suppressing this channel, we significantly attenuate the long-run interaction between policy factors. From a frequency domain analysis, we observe a strong coherence between monetary and fiscal policy factors at lower than and around business cycle frequency that supports the importance of low-frequency policy interaction emphasized in Kliem et al. (2016a,b) and Tan (2019).

The bivariate latent policy regime factor composed of monetary and fiscal policy factors plays a central role in determining the stances of individual policies and their joint behaviors reflected in policy regimes. We therefore interpret it as economic fundamentals or internal information held by policy makers driving changes in individual policy stances and policy interactions. To give a realistic context to monetary and fiscal policy factors, we link each of the estimated policy factors to a large pool of macro and financial variables and select the variables that have significant explanatory power for the monetary and fiscal policy factors using the adaptive least absolute shrinkage and selection operator (LASSO). Selected variables for monetary policy factor cover broader categories of economic variables than those for fiscal policy factor. Some variables, such as net interest payment to government spending ratio and the term structure of interest rates, are selected for both monetary and fiscal policy factors, implying a clear, albeit indirect, evidence of policy interaction.

The rest of the paper is organized as follows. In Section 2, we introduce regime switching policy rules with endogenous feedback, and provide economic interpretations of our model specification. Section 3 presents estimates of monetary and fiscal policy rules, dynamics of policy regime factors, and estimated policy regimes. We provide explanations of the plausibility of estimates and link estimated policy factors to key macro variables via the shrinkage regression approach. Section 4 scrutinizes the impacts of endogenous feedback, dynamic interaction, and contemporaneous coordination on policy interactions in impulse response and frequency domain analyses. Section 5 concludes the paper, and the Appendices provide results from robustness checks and a detailed explanation for the adaptive LASSO method.

2 Policy Rules with Bivariate Policy Regime Factor

In the existing literature, many authors have considered and analyzed interesting economic questions using a broad class of regime switching policy rules. Among many focused on the policy interaction, Davig and Leeper (2006b) consider the monetary and fiscal policy interaction and estimate Markov-switching monetary and fiscal policy rules separately in the single equation estimation approach. Favero and Monacelli (2005) also consider regime switching monetary and fiscal policy rules and find that regime switches in policy rules do not exhibit any degree of synchronization. Gonzalez-Astudillo (2018) generalizes this approach to characterize policy interactions using a joint estimation of monetary and fiscal policy rules and shows a significant comovement between monetary and fiscal policies. Bianchi and Melosi (2017) consider Markov-switching VAR to capture stylized facts after WWII in the U.S. and find that during the zero lower bound period, fiscal shocks play a leading role in explaining the inflation dynamic. Using a Markov-switching dynamic stochastic general equilibrium (DSGE) model, Bianchi (2012) investigates the monetary/fiscal policy mix using historical U.S. data. Bianchi and Ilut (2017) estimate a model for the U.S. economy with monetary/fiscal mix changes and explain why inflation dropped in the 1980s in terms of the policy change.

All of the above are, however, based on the conventional exogenous regime switching model, which assumes that the switching of monetary and fiscal behaviors is entirely exogenous. The major difference between our regime switching policy rules and the existing conventional regime switching policy rules is the presence of endogenous feedback in our regime switching, which describes a purposeful policy decision by reflecting the state of the economy.[4] In our empirical specification, we consider regime switching monetary and fiscal policy rules with endogenous self-feedback and cross-feedback to describe individual policy authority's purposeful behaviors. Moreover, to explicitly describe monetary and fiscal policy interactions, we consider a multivariate equation approach and jointly estimate monetary and fiscal policy rules with dynamic interaction between policy authorities.

2.1 Endogeneity in Regime Switching Policy Rule

We first discuss a generic policy rule with time varying policy coefficients that systematically evolve according to the endogenous regime switching model introduced by Chang et al. (2017). To focus

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[4] 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. Barthélemy and Marx (2017) consider a model that the monetary policy choice is determined by transition probabilities depending on the level of inflation to show conditions for the existence of a unique bounded equilibrium and solution method in regime switching rational expectations models with state-dependent transition probabilities. Their models, however, are not directly comparable to ours, which assumes regimes are determined by latent policy factors including some unobserved economic fundamentals. Note that technically our model may also accommodate the partially observable policy factors with some predetermined variables, e.g. a lagged inflation.

on the essence of the model, we consider a generic policy rule

$$y_t = \beta'_{s_t} x_t + \delta' \eta_t + u_t, \tag{1}$$

where y_t is a policy instrument, x_t are policy target variables believed to be systematically considered by policy makers, η_t is a vector of non-target variables that may also affect y_t, u_t is an error representing policy disturbance, δ is a parameter vector, and β_{s_t} is a vector of state-dependent parameters that we discuss in detail below. The policy disturbance u_t may include policy surprises and other exogenous shocks driving the economy. Both the target x_t and the non-target η_t variables are assumed to be orthogonal to the policy disturbance so that the policy rule (1) can be consistently estimated by the ordinary least squares. The non-target variables η_t may be correlated with the target variables x_t.

In the policy rule, the time varying policy behavior is characterized by the state-dependent coefficients β_{s_t} on the policy target variables x_t which take distinct values depending on the realizations of the state variable s_t. We specify the state variable s_t as a binary process

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

defined with a latent policy factor w_t and a threshold ψ. Policy stance prevailing at time t therefore corresponds to the realized value of s_t, 0 or 1, signifying passive (dovish) or active (hawkish) monetary policy stance, for example. We assume that the latent policy factor w_t follows a stationary autoregressive process

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

with $|\alpha| < 1$, and interpret it as policy maker's internal information used for its policy decision. The innovation v_t drives the policy factor w_t which in turn determines the policy stance s_t. The autoregressive coefficient α therefore measures persistency of policy stance and the level of w_t relative to the threshold ψ indicates strength of the prevailing policy stance.

We allow feedback from the current policy disturbance u_t to the policy factor innovation v_{t+1} next period. Specifically, we assume u_t and v_{t+1} are jointly i.i.d. normal with unit variance and

$$\mathrm{cov}(u_t, v_{t+1}) = \rho$$

The sign and magnitude of ρ represent, respectively, the direction and degree of feedback from u_t to v_{t+1}. This dynamic correlation provides a channel from u_t to v_{t+1} through which the information about the economy relevant for policy making but not captured in the target variables x_t is provided to policy stance determination next period. This is in sharp contrast to the time varying policy rules considered in conventional Markov switching models where policy stance is determined by an exogenous Markov chain.

We call this information channel *endogenous feedback* to reflect the fact that the current policy disturbance u_t contains information about other endogenous economic variables that may affect policy stance determination next period. To be more explicit about the endogenous nature of the feedback, we decompose the policy disturbance as

$$u_t = \gamma' \xi_t + e_t$$

where e_t is the exogenous policy shock representing surprise changes in the policy instrument, ξ_t collects the exogenous shocks generating other endogenous variables relevant to policy making that are not included in the simple policy rule (1), and γ is a parameter vector. For example, if (1) is a monetary policy rule, ξ_t may include a fiscal policy shock. Therefore, through either ξ_t or e_t, the current policy disturbance u_t may affect the innovation v_{t+1} that generates the policy factor w_{t+1} determining the policy stance next period. Precisely in this sense, we say that policy stance determination is endogenous, viz., the shocks generating the endogenous variables driving the current economy affect the future policy stance

2.2 Policy Rules with Regime Switching

We consider a Taylor (1993) type monetary policy rule that links nominal interest rate i_t to inflation π_t and output gap y_t. Unlike monetary policy, there is no widely accepted specification for fiscal policy.[5] We specify a fiscal policy rule that links tax revenues net of transfer payments τ_t to government spending purchases g_t, previous debt held by public b_{t-1}, output gap y_t. For smooth evolution of policy rules, we include lagged policy instruments in addition to the policy target variables in both policy rules. We consider the following bivariate regime switching model of monetary and fiscal policy rules

$$i_t = \alpha_\rho(s_t^m) i_{t-1} + (1 - \alpha_\rho(s_t^m)) \left[\alpha_c(s_t^m) + \alpha_\pi(s_t^m)\pi_t + \alpha_y(s_t^m) y_t\right] + \alpha_\eta^\pi \eta_{\pi,t} + \alpha_\eta^y \eta_{y,t} + \sigma_m u_{m,t} \quad (2)$$

$$\tau_t = \beta_\rho(s_t^f)\tau_{t-1} + (1 - \beta_\rho(s_t^f)) \left[\beta_c(s_t^f) + \beta_b(s_t^f) b_{t-1} + \beta_g(s_t^f) g_t + \beta_y(s_t^f) y_t\right] + \beta_\eta^y \eta_{y,t} + \sigma_f u_{f,t} \quad (3)$$

where $\eta_{\pi,t}$ and $\eta_{y,t}$ are control variables included to correct for potential endogeneity in inflation π_t and output gap y_t, respectively, and $u_{m,t}$ and $u_{f,t}$ are monetary and fiscal policy disturbances representing the parts of policy instruments not predicted by the policy target variables, which we discuss further below. The control variables $\eta_{\pi,t}$ and $\eta_{y,t}$ are obtained as standardized fitted residuals from regressing the potentially endogenous regressors π_t and y_t on a set of instruments including four lags of themselves as well as inflation of commodity price index and M2 growth.[6]

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

[6] Based on a generic policy rule discussed in the previous section, we consider an endogeneity correction method suggested in Kim (2009) that is consistent to our model specification. Handling an endogeneity issue using instrumental variables may not be innocuous from the critique in Sims and Zha (2006) that point out the validity of the instruments used in a univariate regression approach on monetary policy rule.

The coefficients $\alpha_j(s_t^m)$, $j \in \{\rho, c, \pi, y\}$ and $\beta_j(s_t^f)$, $j \in \{\rho, c, b, g, y\}$ capture smoothing and policy parameters in monetary and fiscal policy rules, respectively, that are time varying and dependent on policy stances signified by the binary regime indexes s_t^m and s_t^f.

In the monetary policy rule (2), $s_t^m = 0$ and 1 are policy stances that respond to the inflation weakly and aggressively, respectively. Analogously, in the fiscal policy rule (3), $s_t^f = 0$ and 1 represent policy stances that respond to the debt weakly and strongly. For our subsequent discussions on policy regime identification and policy interactions, we borrow terminologies from Leeper (1991) which defines regimes for monetary policy (MP) and fiscal policy (FP) by the values of the parameters (α_π and β_b) in simplified monetary and fiscal policy rules in a DSGE model. Monetary policy is defined to be active when it responds strongly to inflation by more than one-to-one, and passive when it responds weakly to inflation. Similarly, fiscal policy is defined as active when it reacts weakly to debt, and passive when it reacts strongly to debt, reflecting the cost of servicing the debt. Depending on the values of these parameters, we have four possible monetary and fiscal policy regimes, including two determinate regimes, active monetary/passive fiscal (AM/PF) and passive monetary/active fiscal (PM/AF), one indeterminate regime, passive monetary/passive fiscal (PM/PF), and one explosive regime, active monetary/active fiscal (AM/AF). We use two determinate regimes, AM/PF and PM/AF, interchangeably with regime M and regime F, respectively.

In our specification, monetary and fiscal policy disturbances $(u_{m,t}, u_{f,t})$ represent the responses of the policy makers to the state of the economy beyond what is reflected in the policy target variables. Our interpretation of the monetary policy disturbance $u_{m,t}$ is consistent with the view that the Fed's primary objectives are to achieve stable inflation and sustainable economic growth, while at the same time, the Fed has reacted to emerging economic states purposefully and intermittently.[7] A fiscal policy disturbance $u_{f,t}$ may contain similar economic concerns as those faced by monetary authority, but it may also include some additional concerns unique to fiscal policy makers, including a multitude of political considerations.

2.3 Policy Regime Factors with Endogenous Feedback

We specify regime index s_t^i, $i \in \{m, f\}$ in monetary and fiscal policy rules as

$$s_t^i = 1\{w_{i,t} \geq \psi_i\}$$

with a latent policy regime factor $w_{i,t}$ and a threshold ψ_i. The bivariate latent regime factor $w_t = (w_{m,t}, w_{f,t})'$ evolves as a stationary vector autoregressive process

$$w_t = Aw_{t-1} + v_t \tag{4}$$

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[7] Taylor (1993) [p. 202-203] states "What is perhaps surprising is that this (simple Taylor) 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 respond to the crash in the stock market by easing interest rates." This statement supports our interpretation on $u_{m,t}$.

driven by the innovation $v_t = (v_{m,t}, v_{f,t})'$. The autoregressive coefficient matrix

$$A = \begin{pmatrix} a_{mm} & a_{mf} \\ a_{fm} & a_{ff} \end{pmatrix}. \tag{5}$$

determines dynamic interactions between the policy factors $w_{m,t}$ and $w_{f,t}$. We allow for dynamic feedback from current policy disturbances $u_t = (u_{m,t}, u_{f,t})'$ to next period policy stances, and refer to it as *endogenous feedback* reflecting the endogenous nature of the policy disturbances. Let $u_t = (u_{m,t}, u_{f,t})'$, and assume

$$(u_t', v_{t+1}')' \sim i.i.d\ \mathbb{N}(0, P)$$

with a correlation matrix

$$P = \begin{pmatrix} P_{uu} & P_{uv} \\ P_{vu} & P_{vv} \end{pmatrix} = \begin{pmatrix} 1 & & & \\ \rho_{u_m,u_f} & 1 & & \\ \rho_{v_m,u_m} & \rho_{v_m,u_f} & 1 & \\ \rho_{v_f,u_m} & \rho_{v_f,u_f} & \rho_{v_m,v_f} & 1 \end{pmatrix}. \tag{6}$$

The dynamics of policy regime factor explicitly describes the determination of monetary and fiscal policy stances and their interaction through the AR coefficient matrix A in equation (5) and the correlation matrix P in equation (6). We consider three channels that capture the existence of policy interactions and quantify their strength subsequently. First of all, the vector of policy factors w_t specified in equation (4) evolves through the A indicating an interaction between current and lagged policy factors. We refer to it as the *dynamic interaction channel* because the A directly captures the effects of past policy factor on current policy factor. Specifically, diagonal terms in A show the persistence of each policy authority's stance and off-diagonal terms quantify the coordination with other policy authority by responding to its own past policy factor and other policy authority's past policy factor.

Second, we can infer from the estimated P about the underlying mechanism of how one policy disturbance dynamically influences its policy stance and the other policy authority's stance. We say that there is endogenous feedback in the regime switching if $P_{vu} \neq 0$, and that the regime switching is exogenous if otherwise. We will refer to the policy interaction through the P as the *endogenous feedback channel* in which there are two types of feedback. First, *self-feedback* can be captured by a correlation between the current monetary (fiscal) policy disturbance and the next period innovation of latent monetary (fiscal) policy factor. For the monetary authority, self-feedback ρ_{v_m,u_m} measures impact from $u_{m,t}$ to $v_{m,t+1}$, and therefore $w_{m,t+1}$. Second, a correlation between the current monetary (fiscal) policy disturbance and the next period innovation of latent fiscal (monetary) policy factor measures *cross-feedback*. Specifically, cross-feedback from monetary policy to fiscal policy ρ_{v_f,u_m} captures how current monetary policy disturbance $u_{m,t}$ influences next period fiscal policy factor innovation $v_{f,t+1}$. Therefore, if the monetary policy disturbance $u_{m,t}$

materializes at t, it will affect the change in monetary policy choice next period $\alpha_\pi(s^m_{t+1})$ through the self-feedback, and the switching in fiscal policy stance $\beta_b(s^f_{t+1})$ via the cross-feedback.

Self-feedback and cross-feedback influence the evolution of monetary and fiscal policy factors, as the P is involved in a calculation of time-varying transition probability between possible policy regimes in our specification. To describe the idea, we consider time-varying transition probabilities in the endogenous regime switching model introduced in Chang et al. (2020). By decomposing policy factor innovations v_t by purging out the effect of realized policy disturbances u_{t-1}, we let

$$\varepsilon_t = v_t - P_{vu}P_{uu}^{-1}u_{t-1} \sim \mathbb{N}(0, P_{vv\cdot u})$$

then we have a transitional probability from regime F to regime F

$$\mathbb{P}\Big\{S_t = (0,0)' | S_{t-1} = (0,0)', \mathcal{F}_{t-1}\Big\} = \int_{-\infty}^{\psi} \Phi_{v|u}(\psi - P_{vu}P_{uu}^{-1}u_{t-1} - Aw_{t-1})\phi(w_{t-1})dw_{t-1} \Big/ \Phi(\psi)$$

where $\Phi_{v|u}$ is the distribution function of ε_t, $\psi = (\psi_m, \psi_f)'$, $u_{t-1} = (u_{m,t-1}, u_{f,t-1})'$ and $\mathcal{F}_{t-1}$ the information set spanned by past policy instruments, policy variables and endogeneity correction factors. We zoom in the $P_{vu}P_{uu}^{-1}u_{t-1}$ in a transition probability and let $P_{uu} = I$ to emphasize the role of self-feedback and cross-feedback in time-varying transition probabilities. This component can be decomposed into self-feedback and cross-feedback as below

$$P_{vu}P_{uu}^{-1}u_{t-1} = \begin{pmatrix} \overbrace{\rho_{v_m,u_m}}^{\text{Self-feedback}} u_{m,t-1} + \overbrace{\rho_{v_m,u_f}}^{\text{Cross-feedback}} u_{f,t-1} \\ \underbrace{\rho_{v_f,u_m}}_{\text{Cross-feedback}} u_{m,t-1} + \underbrace{\rho_{v_f,u_f}}_{\text{Self-feedback}} u_{f,t-1} \end{pmatrix}$$

If $P_{vu} > 0$ element-wise, then a positive disturbance to either policy rule, $u_{i,t-1} > 0$, $i \in \{m, f\}$ makes monetary and fiscal authorities being more active and passive, respectively and therefore, staying in regime F less likely in the next period through both self-feedback and cross-feedback channels.

Lastly, we quantify the *contemporaneous policy coordination* using the correlation between current policy factor innovations v_t net of dynamic influence from u_{t-1} through feedback. We explicitly measure it by $\rho_{vv\cdot u} \equiv P_{vv\cdot u}^{(2,1)}$ where $P_{vv\cdot u} = P_{vv} - P_{vu}P_{uu}^{-1}P_{uv}$. This allows us to investigate the existence and magnitude of policy authorities' coordination in determining their policy stances contemporaneously. The existence of contemporaneous policy coordination implies that monetary and fiscal authorities may update their policy stances not only by observing changes in past policy instruments u_t but also by inferring changes in policy regime factor w_t.

3 Data and Estimation Results

In this study, we use quarterly U.S. data from 1961:1 to 2014:2. To estimate the monetary policy rule, we set π_t to be the inflation rate over the contemporaneous and prior three quarters, as in Taylor (1993), and obtain the inflation each period as log difference of the GDP deflator. For the nominal interest rate i_t, we use the three-month Treasury bill (T-bill) rate in the secondary market. The output gap is the log difference between real GDP and the Congressional Budget Office's measure of potential real GDP. For the estimation of the fiscal policy rule, we use fiscal variables for the federal government only. Variables used in the fiscal policy rule, except for the output gap, are transformed to real per capita variables.[8] We let τ_t be the real per capita federal tax receipts net of total federal transfer payments, and b_t the real per capita market value of gross marketable federal debt held by the public,[9] and g_t the real per capita federal government consumption plus investment expenditures. Monetary policy variables are obtained from the Federal Reserve Bank of St. Louis, Economic Data-FRED, and fiscal policy variables from NIPA Table 3.2 (τ_t, g_t), and Federal Reserve Bank of Dallas, U.S. Economic Data and Analysis (b_t). To handle potential endogeneity issue, we consider commodity price inflation and M2 growth that are constructed by the percentage change over last four quarters of commodity price index and seasonally adjusted M2, respectively. Both variables are available from the FRED database.

Our regime switching monetary and fiscal policy rules are jointly estimated by the maximum likelihood method using a modified Markov switching filter developed by Chang et al. (2020). Our joint estimation of monetary and fiscal policy rules provides estimates of monetary and fiscal policy rules and policy regime factor dynamics, including thresholds, the AR coefficient and correlation matrices specified in the previous section. Table 1 reports the maximum likelihood estimates and 90% confidence intervals obtained By simulating the sampling distribution around MLE.[10] Figure 1 presents the extracted monetary and fiscal policy factors and estimated policy regimes that are jointly determined by policy factors $w_{i,t}$ and thresholds ψ_i for $i = \{m, f\}$. In following subsections, we provide estimates of policy rules and dynamics of policy regime factor, plausibility of estimates, and interpretation of policy regime factors in details.

3.1 Estimates of Regime Switching Policy Rules

We may infer from the estimates of state dependent parameters on inflation α_π in the left panel of Table 1 that monetary policy switches between passive when central bank responds weakly to inflation ($\alpha_{\pi,0}$=0.60), and active when it responds strongly to inflation ($\alpha_{\pi,1}$=1.76). In our model, the monetary policy stance is determined depending on whether the extracted monetary policy factor $w_{m,t}$ is below or above the estimated threshold ψ_m, as shown in the upper panel of Figure

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[8] The GDP deflator is used to deflate the series to dollars of 2005, and the total population is used to transform the series to per capita terms. Both time series are obtained from the FRED database.

[9] We use the average real per capita debt over previous four quarters as a measure of b_{t-1}.

[10] We obtain confidence intervals by estimating 1000 simulated samples at the maximum likelihood estimate.

Table 1: Estimation Results for Endogenous Regime Switching Policy Rules

Monetary Policy Rule			Fiscal Policy Rule			Regime Factor Dynamics		
Parameter	Estimate	90% CI	Parameter	Estimate	90% CI	Parameter	Estimate	90% CI
$\alpha_{\rho,0}$	0.711	[0.680,0.742]	$\beta_{\rho,0}$	0.117	[0.004,0.392]	ψ_m	0.611	[-0.527,1.923]
$\alpha_{\rho,1}$	0.755	[0.709,0.796]	$\beta_{\rho,1}$	0.946	[0.925,0.962]	ψ_f	-2.472	[-3.845,-1.794]
$\alpha_{c,0}$	1.746	[1.236,2.215]	$\beta_{c,0}$	3.313	[3.120,3.531]	a_{mm}	0.152	[-0.217,0.615]
$\alpha_{c,1}$	1.430	[0.299,2.289]	$\beta_{c,1}$	1.865	[0.864,2.813]	a_{fm}	0.053	[0.045,0.100]
$\alpha_{\pi,0}$	0.603	[0.509,0.696]	$\beta_{b,0}$	0.083	[0.081,0.083]	a_{mf}	1.128	[0.405,1.609]
$\alpha_{\pi,1}$	1.758	[1.527,2.018]	$\beta_{b,1}$	0.124	[0.083,0.184]	a_{ff}	0.719	[0.579,0.844]
$\alpha_{y,0}$	0.412	[0.303,0.512]	$\beta_{y,0}$	0.342	[0.288,0.427]	$\rho_{u_m u_f}$	0.155	[0.030,0.295]
$\alpha_{y,1}$	-0.004	[-0.190,0.184]	$\beta_{y,1}$	0.285	[0.164,0.422]	$\rho_{v_m u_m}$	0.863	[0.430,0.978]
α_η^π	0.124	[0.039,0.206]	$\beta_{g,0}$	-0.312	[-0.328,-0.284]	$\rho_{v_f u_m}$	0.718	[0.461,0.967]
α_η^y	0.041	[-0.021,0.104]	$\beta_{g,1}$	-0.031	[-0.316,0.230]	$\rho_{v_m u_f}$	0.409	[-0.030,0.726]
σ_m	0.467	[0.404,0.494]	β_η^y	0.026	[0.009,0.042]	$\rho_{v_f u_f}$	0.175	[0.063,0.716]
			σ_f	0.137	[0.121,0.146]	$\rho_{v_m v_f}$	0.930	[0.748,0.993]
						$\rho_{vv\cdot u}$	0.293	[0.036,0.642]

1. Therefore, we may use the phrase ‘passive (active) monetary policy stance’ interchangeably with ‘the monetary policy factor is below (above) the estimated threshold’. When the central bank responds to inflation weakly (passive monetary stance), more attention is given to the output gap in comparison to the stance that the monetary authority puts more weight on inflation control (active monetary stance). Regardless of the prevailing policy stance, passive or active, we find clear evidence of smooth adjustment of the interest rate with respect to the target interest rate.[11]

The middle panel of Table 1 shows that fiscal policy switches between active and passive by responding to debt relatively weakly and strongly ($\beta_{b,0}$=0.08 and $\beta_{b,1}$=0.12). Here we use the phrase ‘active (passive) fiscal policy stance’ interchangeably with ‘the extracted fiscal policy factor below (above) estimated threshold’ as in the lower panel of Figure 1. According to our estimation, in both fiscal policy stances, taxes are raised systematically and strongly with respect to the output gap, as one would expect from built-in stabilizers in the tax system. When the fiscal authority takes an active fiscal stance by responding to the debt relatively weakly, estimates of the fiscal policy rule show that tax revenues and government spending move in the opposite way. These estimates describe the fiscal behaviors during the recession after the recent financial crisis: several tax cuts and increased government spending as part of government stimulus packages. At the same time, fiscal authority responds to the debt weakly, reaching an unusual debt level. A passive fiscal stance is characterized by a strong response to the debt by putting more attention on debt stabilization. The estimated smoothing coefficients of the fiscal policy rule imply different smoothing behaviors depending on fiscal policy purposes. When the fiscal policy pays less attention to the debt, a strong adjustment with respect to the target occurs every quarter, however when fiscal policy has the clear role of stabilizing debt, about 5% of the adjustment occurs with respect to the target. Monetary and fiscal policy stances are identified by policy regime factors together with thresholds and jointly determine how both policy authorities have interacted, i.e., policy regime.

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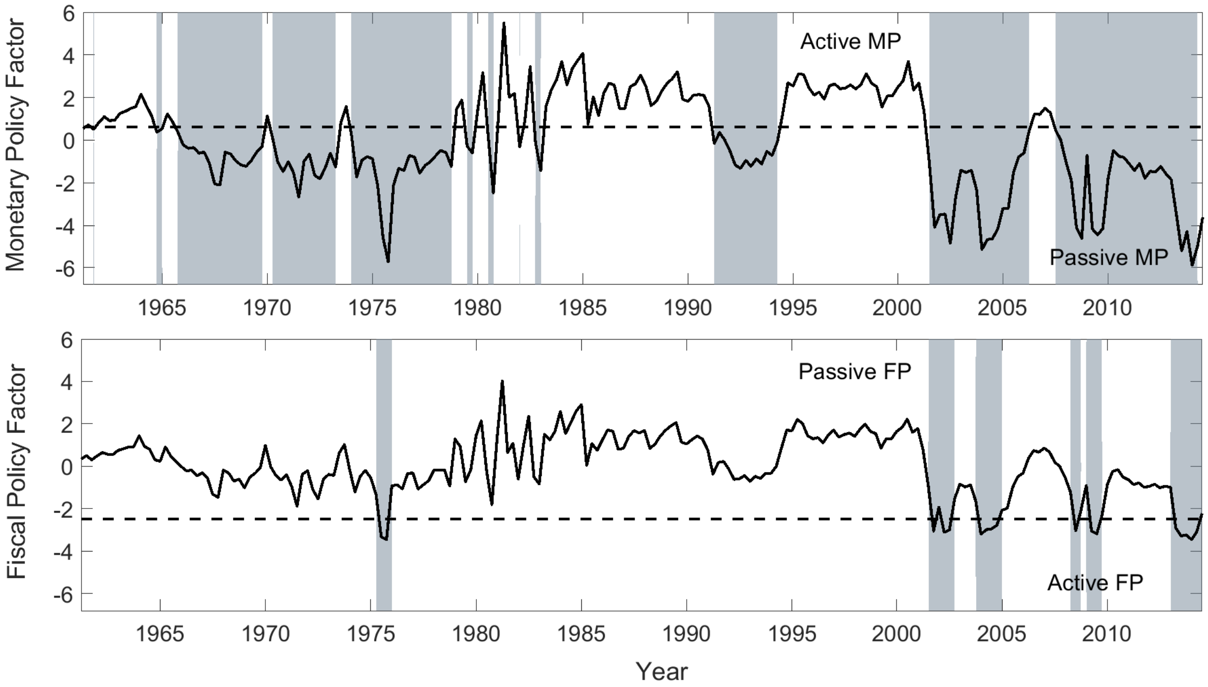
[11] A strong smoothing behavior in monetary policy rule has been studied empirically, and a variety of plausible reasons of smoothing behavior has been discussed in literature: broadly, fear of financial market disruption, managing market expectations, uncertainties in model and data, and confidence in monetary authority.

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



Notes: The solid and dashed lines on upper and lower graphs, respectively, present the extracted policy factors and corresponding thresholds from monetary (upper) and fiscal (lower) policy rules. The shaded areas on upper and lower panels indicate the passive monetary policy stance and active fiscal policy stance.

In the following subsection, we will describe estimates of policy regime factor dynamics, including three statistical measures of policy interaction; the dynamic interaction, endogenous feedback, and contemporaneous policy coordination.

3.2 Estimates of Policy Regime Factor Dynamics

The right panel of Table 1 shows the estimated thresholds ψ_m and ψ_f, the AR coefficient matrix A, and the correlation matrix P that are relevant to the dynamics of policy regime factors and the determination of policy regimes. Three noticeable findings follow. First, we observe that a fiscal policy factor significantly impacts monetary policy factor dynamically in a way that a monetary authority responds to inflation more (less) aggressively when fiscal authority paid more (less) attention to debt stabilization. From the estimates of the off-diagonal elements of A, we observe that monetary policy factor $w_{m,t}$ responds to the lagged fiscal policy factor $w_{f,t-1}$ strongly (a_{mf}=1.13), while the fiscal policy factor $w_{f,t}$ responds to the lagged monetary policy factor $w_{m,t-1}$ weakly (a_{fm}=0.05). Therefore, we may say that next period monetary policy factor can be explained by the current fiscal policy factor; however next period fiscal policy factor can not be explained by current monetary policy factor. This finding implies that monetary authority adjusts the strength of its policy stance by reflecting on fiscal authority's policy stance more than the fiscal authority does.

Second, we find strong evidence of endogenous feedback. Recall that our endogenous regime switching policy rules are equivalent to those of exogenous Markov switching policy rules, if an endogenous feedback channel is shut down, P_{vu}=0. We show that a past monetary policy disturbance $u_{m,t-1}$ influences monetary and fiscal policy stances determined by $w_{m,t}$ and $w_{f,t}$ along ψ_m and ψ_f through self-feedback and cross-feedback. Specifically, we find ρ_{v_m,u_m}=0.86 and ρ_{v_f,u_m}=0.72. The strong self-feedback we observe in the monetary policy rule means that a positive monetary policy disturbance $u_{m,t}$ in the current period would forecast a higher monetary policy factor $w_{m,t+1}$, which implies that active monetary policy is more likely in the next period. For example, if news contained in stock prices portends higher future inflation, but does not yet affect inflation today, this positive disturbance would raise the nominal interest rate above the level that the current inflation predicts. A positive policy disturbance forecasts a higher monetary policy factor, which means a monetary authority would respond more aggressively to inflation in the next period. The strong cross-feedback from past monetary policy disturbance $u_{m,t-1}$ to current fiscal policy factor $w_{f,t}$ indicates that a monetary policy disturbance can influence fiscal policy behavior. For example, a positive $u_{m,t-1}$ raising interest rate and inducing a strong response to future inflation can influence systematic response of fiscal behavior to stabilize debt directly. In our estimate, with a positive monetary policy disturbance that makes monetary policy more active, fiscal authority tends to put more attention to stabilizing debt.

In contrast to strong endogenous feedback from a monetary policy disturbance, a fiscal policy disturbance generates a weak self-feedback to fiscal policy factor (ρ_{v_f,u_f}=0.17) and a moderate cross-feedback to monetary policy factor (ρ_{v_m,u_f}=0.41), albeit the latter one is statistically insignificant at 90% confidence level. Fiscal policy disturbances mainly capture exogenous one-time events and therefore they are not reflected in fiscal authority's purposeful behaviors such as systematic responses to debt stabilization or discretionary economic stimulus. The cross-feedback from fiscal policy disturbance to next period monetary policy stance may capture the fact that central bank routinely predicts fiscal policy instrument and targets. For example, an expansionary fiscal policy disturbance, regardless of whether it is exogenous or endogenous by nature, directly induces nominal and real impacts to the economy, and monetary policy may systematically adjust its stance based on fiscal policy disturbance. In sum, we observe that a monetary policy authority strongly adjusts its policy stance via both self-feedback and cross-feedback, while a fiscal policy authority updates its policy stance primarily through cross-feedback.

Lastly, we observe significant contemporaneous coordination between two policy authorities. A strong correlation between policy factor innovations (ρ_{v_m,v_f}=0.93) represents a strong positive co-movement between monetary and fiscal policy factors inducing either AM/PF or PM/AF regime. The strong correlation comes from two sources: endogenous feedback from past policy disturbance to current policy factor innovation and contemporaneous policy coordination. By purging effects from past policy disturbances u_{t-1} out of correlation between policy factor innovations ρ_{v_m,v_f}, we obtain a strong contemporaneous correlation between policy factor innovations ($\rho_{vv\cdot u}$=0.29).

3.3 Plausibility of Estimates

In our endogenous regime switching specification, underlying policy regime is jointly identified by extracted monetary and fiscal policy regime factors and corresponding thresholds as shown in Figure 1. We now examine the plausibility of estimated policy regimes based on a historical narrative on monetary and fiscal policies. Our estimated policy regimes seem quite consistent with narrative accounts of policy history.[12] The shaded areas in the upper panel of Figure 1 shows the estimated passive monetary policy that central bank responds to inflation weakly. Except for a period in 1961:1-1966:1, monetary policy was overall passive until October 1979 when the Fed changed operating procedures and responded to inflation aggressively. Since 1979, monetary policy has been 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 passive monetary policy behavior in the early 1990s and 2000s. During policy deliberations at the 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 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 (1993)). Monetary policy became active when the Fed launched its preemptive strike against inflation in 1994. Also, there were 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 a monetary policy stance was active during 2006:3-2007:4. Prior to 2006:3, the interest rate had increased and was kept high until 2007:3. At the 2006 August meeting, Governor Lacker expressed he thoughts that some inflation risks remained and that he even preferred an increase of the federal funds rate target. Also, at the 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 a relatively high FFR target during this period based on concerns related to potential inflation pressure.[13] After the recent financial crisis, the monetary policy had become passive, and the target for the FFR had been set at between 0 and 1/4 percent by the end of our sample period.

For the fiscal policy stances, the shaded areas in the lower panel of Figure 1 shows the estimated active fiscal policy that fiscal authority puts less attention to debt stabilization. Overall, the estimated fiscal policy stances accord well with the narrative accounts of the important historical episodes. During our sample period, the fiscal policy was mainly passive except for some temporal changes to active fiscal stance. The periods of the active fiscal policy are related to discretionary active tax policy and economic recession periods. The 1975 fiscal expansion, initiated by President Ford's tax cut following the oil price shock, was detected as an active fiscal stance. During the

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

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

periods that monetary policy remained in an active stance, fiscal authority behaved in a passive manner. Through subsequent tax reductions in 2002 and 2003, President Bush made fiscal policy active.

In 2008, Congress passed the Economic Stimulus Act to boost the economy from the recession after the 2007-2008 financial crisis, and fiscal policy became active. The recent period 2010-2013, however, was not detected as a period of active fiscal policy in contrast to a prevailing belief about fiscal policy behavior. During this period, we observe that increases in government spending and decreases in tax revenues slow down, and the debt level decreases compared to those from previous years. Our estimated fiscal policy stance and dynamic of fiscal policy factor after the financial crisis was confirmed from FOMC statements and minutes. In FOMC meetings from January 2009 to December 2009, several FOMC statements mention that joint fiscal and monetary stimulus will contribute to a strengthening of economic growth. In FOMC meetings from March 2013 to October 2013, however, expressions about the fiscal policy stance included in the FOMC statements are concerned about restrictive fiscal policy, and say that fiscal policy has become somewhat more restrictive and is restraining sufficient economic growth. Then, the FOMC statements state that the fiscal policy is restraining economic growth, although the extent of this restraint may be diminishing.[14]

In sum, we observe that underlying policy regime was AM/PF regime in the early sample period. During 1970s, estimated policy regime was mainly PM/PF regime with a short period of PM/AF regime.[15] During the Volcker period, it is well known that monetary authority aggressively responded to inflation, and AM/PF regime became a dominant policy combination. More recently, following to the recent financial crisis, estimated policy regime was switched from AM/PF to PM/AF regime, as discussed earlier. We find that monetary policy stance was mainly passive after the financial crisis while, fiscal policy stance was mixed, and therefore both PM/AF and PM/PF regimes were observed. Our identified fiscal policy stance and FOMC statements related to the recent fiscal policy behaviors indicate that the fiscal policy stance may not have been strong enough to support the economic stimulus after the financial crisis along with the passive stance of the monetary authority.

3.4 Understanding Policy Regime Factors

In this subsection, we explore the implications of estimated monetary and fiscal policy factors on policy interactions. We observe that policy stances may not be cooperating at all time with periods that both policy authorities behave passively, but the underlying policy factors appear to co-move

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[14] See FOMC statements released on December 16, 2009, March, 20, 2013, and March, 19, 2014.

[15] Bhattarai et al. (2016) find that PM/PF regime prevailed in the pre-Volcker period using a fixed-regime DSGE model with monetary and fiscal policy interactions. Davig and Leeper (2006b) and Bianchi and Ilut (2017) consider regime-switching DSGE models and find that PM/AF regime was a dominant regime in the period. More recently, Ettmeier and Kriwoluzky (2020) estimate a DSGE model with policy interactions employing a sequential Monte Carlo algorithm and show that both PM/PF and PM/AF were dominant regimes in the pre-Volcker period.

consistently.[16] Several empirical studies on policy interaction using regime switching specifications find moderate or weak coordination in policy regime. Favero and Monacelli (2005) and Bianchi (2012) find that monetary and fiscal policy regime is not synchronized with several non-cooperating periods, and monetary and fiscal authorities cannot credibly commit to following either AM/PF or PM/AF regime always. However, those findings do not mean that one policy authority ignores another policy authority's behavior or ignorant to the outcome of lack of cooperation. Monetary and fiscal authorities understand a strong interdependence between two policy authorities, as quoted in Bianchi and Melosi (2019). By using policy regime factors instead of estimated policy regimes, we capture a clear co-movement between policy authorities' systematic interaction and may consider it as an implicit intention to pursue coordination between monetary and fiscal policies. Deviations from coordinated policy regime (PM/PF or AM/AF) represent that one policy authority's change in policy stance responding to other policy authority's behavior is not strong enough to cross a threshold.

Estimated policy regime factors allow us to understand policy interaction by linking the policy factors and key macro variables. We interpret latent policy factors as an internal information set of policy authorities, and each policy authority determines its policy rule based on the internal information. Estimated policy factors, therefore, can be interpreted as inferred factors representing observable part of internal information of policy makers, and can be used in policy analyses as natural proxies for internal information of policy authorities about their policy stances. We aim to pin down the variables that explain the policy factors determining the monetary and fiscal policy stances as we interpret the policy factor as the policy makers' internal information set. To do so, we relate our policy factor to macroeconomic and financial variables that are commonly considered in policy studies. To build a pool of the candidate macro-finance variables that may have explanatory power for policy factors, we consider a big data set known as FRED-QD that are widely used in empirical studies. The data set is available from the Federal Reserve Bank of St. Louis and detailed data construction and transformation can be found in McCracken and Ng (2020).[17] We use 216 quarterly time series among original 248 time series in FRED-QD by excluding some time series that are not available from 1961:1. In addition, we add the output gap and six more fiscal variables to understand better whether and how monetary and fiscal policy factors are explained by macro and fiscal variables. The six additional fiscal variables include the ratios of net interest payment to government expenditure, net interest payment to debt, debt real per capita, government spending real per capita, military spending to GDP, and tax revenues real per capita. Policy instrument variables, short-term interest rate and tax revenues real per capita are excluded in our analysis of monetary and fiscal policy 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 223 variables mentioned above as poten-

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[16] The correlation between policy factors based on our estimates is 0.98, implying a strong co-movement between two policy factors.

[17] https://research.stlouisfed.org/econ/mccracken/fred-databases/

tial 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 of our implementation of the adaptive LASSO method is provided in the Appendix.

Table 2: Selected Variables for Monetary and Fiscal Policy Factors

Selected Variables for **Monetary Policy Factor**	Category
10 year T-bill minus 3 month T-bill rate	Interest rates
Net interest payment/outlay ratio	Monetary and fiscal
University of Michigan: consumer sentiment	Consumer expectation
Capacity utilization: manufacturing	Industrial production
Nonfarm business sector: unit labor cost	Earnings and productivity
Output gap	Monetary and fiscal
Industrial production: business equipment	Industrial production
Nonfarm business sector: unit nonlabor payments	Earnings and productivity
Aaa corporate bond minus federal funds rate	Interest rates
1 year T-bill minus 3 month T-bill rate	Interest rates
Average weekly overtime hours: manufacturing	Employment
Real nonfinancial noncorporate business sector assets	Employment
Industrial production: durable and non-durable materials	Industrial production
Gross private domestic investment: chain-type price index	Prices
S&P's composite common stock: P/E ratio	Stock markets
Real estate loans at all commercial banks	Money and credit
Total real non-revolving credit owned and scrutinized	Money and credit
Real M1 money stock	Money and credit
Real estate assets of households	Household Balance Sheets
Real gross private domestic investment: nonresidential	NIPA
Producer price index by commodity intermediate materials	Prices
Switzerland/U.S. exchange rate	Exchange rates

Selected Variables for **Fiscal Policy Factor**	Category
10 year T-bill minus 3 month T-bill rate	Interest rates
Net interest payment/outlay ratio	Monetary and fiscal
Output gap	Monetary and fiscal
University of Michigan: consumer sentiment	Consumer expectation
S&P's composite common stock: P/E ratio	Stock markets
Real estate loans at all commercial banks	Money and credit
Industrial production: durable materials	Industrial production

Table 2 reports the selected variables for policy factors from adaptive LASSO.[18] The top panel of Table 2 presents twenty-two variables from the selected model for the monetary policy factor and the categories they belong to. Naturally, the variables that are commonly considered in an analysis of monetary policy are also selected with relatively large coefficient estimates. They include price index, term structure of interest rates, industrial production, and employment. The selected consumer sentiment index reflects how private agents feel short-term and long-term economic con-

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[18] Selected variables are listed in descending order by absolute value of estimated coefficients and based on the contemporaneous relationship between the levels of policy factors and the variables reflecting the macroeconomic environment.

ditions. Changes in monetary policy stance can signal private agents the future economic condition and build their expectations. Also net interest payment to government spending ratio is selected as one of the important variables that explain a level of monetary policy factor. Colored variables denote commonly selected variables for both policy factors. We observe that selected variables for monetary policy factor cover more categories of economic variables than those for fiscal policy factor.

Similarly, the bottom panel of Table 2 presents seven variables from the selected model for the fiscal policy factor and the categories they are associated with. Selected variables are a subset of ones from monetary policy factor. Net interest payment to government spending ratio is selected with large estimated coefficients, and several variables related to interest rates are selected for the fiscal policy factor, implying that fiscal policy stance is closely related to the term structure of interest rates. For both policy regime factors, interest rate, production, stock and credit market, consumer sentiment, and net interest payment to outlay ratio are commonly selected.

The most important finding from the adaptive LASSO analysis is that the fiscal variable, net interest payment to government spending ratio, is selected to be one of the most important variables explaining both monetary and fiscal policy factors. When the monetary authority controls inflation strongly by raising an interest rate, an interest payment burden may be increased on existing government debt, and it can be a strong incentive to change tax policy rules in a way to stabilize the debt. 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. This variable may reflect a strong incentive of politicians to respond to monetary policy regime change. Our findings here help us infer what policy makers consider in their decision making, and they show a clear, albeit indirect, evidence of policy interaction.[19] In the following section, we scrutinize monetary and fiscal policy interactions in both impulse response and frequency domain analyses.

4 Policy Interactions

While economic theory emphasizes how policies in particular monetary and fiscal stances must interact to determine the price level uniquely, some 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. (2016a,b)). Recently, more works explore dynamic interactions between monetary and fiscal *policy rules* via regime switching models in a single equation model or a Markov-switching DSGE model, in an effort to learn more beyond what the sample correlation among *policy variables* can reveal (Favero and Monacelli (2005), Davig and Leeper (2006b), Chung et al. (2007), Gonzalez-Astudillo (2013), Bianchi (2012), and Bianchi and Ilut (2017)). This line of exploration

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[19] By adding our extracted policy regime factors as proxies of changes in monetary and fiscal policy stances, one may investigate how the policy factors are related to and affected by state of general economy in various econometric models.

gives an interpretation based on policy interactions that is consistent with what economic theories predict. Most literature however treats changes in policy behavior as exogenous, evolving independently of the state of the economy. It is difficult to rationalize such exogenous policy changes as an actual purposeful policy behavior responding systematically to changes in the macroeconomic environment.

We aim to elicit the purposeful nature of policy making to better understand the interaction between monetary and fiscal policies. With our new endogenous regime switching model of monetary and fiscal policy rules, we are able to explicitly characterize the ways in which policy makers may interact using three channels we established earlier. They include endogenous feedbacks from policy disturbances to regime factors, dynamic interactions of regime factors and contemporaneous coordination among policy factors. We demonstrate how we quantify each of these three channels in our subsequent investigation of monetary and fiscal policy interactions.

4.1 Decomposing Policy Disturbances and Policy Factor Innovations

We identify the structural shocks driving the policy instruments, i_t and τ_t, and the policy factors, $w_{m,t}$ and $w_{f,t}$, that determine monetary and fiscal authorities' individual policy stances and the resulting policy combinations by assuming the following contemporaneous relationships between the current policy disturbances, $u_{m,t}$ and $u_{f,t}$, and the next period policy factor innovations, $v_{m,t+1}$ and $v_{m,t+1}$:

$$\begin{aligned}
u_{f,t} &= e_{f,t} \\
u_{m,t} &= \lambda e_{f,t} + \sqrt{1-\lambda^2}\, e_{m,t} \\
v_{f,t+1} &= \phi_{11} e_{f,t} + \phi_{12} e_{m,t} + \sqrt{1-\phi_{11}^2-\phi_{12}^2}\, \varepsilon_{f,t+1} \\
v_{m,t+1} &= \phi_{21} e_{f,t} + \phi_{22} e_{m,t} + \phi_{23} \varepsilon_{f,t+1} + \sqrt{1-\phi_{21}^2-\phi_{22}^2-\phi_{23}^2}\, \varepsilon_{m,t+1}.
\end{aligned}$$

The four orthogonal shocks on the right hand side of the above equations, $e_{f,t}, e_{m,t}, \varepsilon_{f,t+1}$, and $\varepsilon_{m,t+1}$, are assumed to be standard normal, independent of each other at all leads and lags. The six coefficients, $\lambda, \phi_{11}, \phi_{12}, \phi_{21}, \phi_{22}$ and ϕ_{23}, are assumed to be strictly less than 1, and satisfy $\phi_{11}^2+\phi_{12}^2 \leq 1$ and $\phi_{21}^2+\phi_{22}^2+\phi_{23}^2 \leq 1$ so that the four shocks are properly defined.

The above four equations form a just-identified triangular system as can be seen clearly from their matrix form representation, viz.,

$$\begin{pmatrix} u_{f,t} \\ u_{m,t} \\ v_{f,t+1} \\ v_{m,t+1} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ \lambda & \sqrt{1-\lambda^2} & 0 & 0 \\ \phi_{11} & \phi_{12} & \sqrt{1-\phi_{11}^2-\phi_{12}^2} & 0 \\ \phi_{21} & \phi_{22} & \phi_{23} & \sqrt{1-\phi_{21}^2-\phi_{22}^2-\phi_{23}^2} \end{pmatrix} \begin{pmatrix} e_{f,t} \\ e_{m,t} \\ \varepsilon_{f,t+1} \\ \varepsilon_{m,t+1} \end{pmatrix},$$

which we may write more compactly as

$$\mathbf{u}_t = \Phi \mathbf{e}_t. \tag{7}$$

We may view (7) as a structural VAR model defined with four structural shocks in

$$\mathbf{e}_t = (e_{f,t}, e_{m,t}, \varepsilon_{f,t+1}, \varepsilon_{m,t+1})'$$

that can be recursively identified from the covariance matrix P of the reduced form innovations

$$\mathbf{u}_t = (u_{f,t}, u_{m,t}, v_{f,t+1}, v_{m,t+1})'.$$

The matrix Φ represents impulse response at impact. Due to the triangular structure, Φ is just-identified and can be easily obtained from the Choleski decomposition of the estimated covariance matrix P of $\mathbf{u}_t$. Indeed there is a one-to-one mapping between the parameters in Φ and those in the lower triangular matrix L of the Cholesky decomposition of $P = LL'$.

Our identifying assumption on the contemporaneous relationship between the monetary and fiscal policy disturbances, $u_{m,t}$ and $u_{f,t}$, are based on the exogeneity of fiscal policy disturbance observed in the existing literature. Several studies on fiscal policy rule demonstrate that fiscal policy is more exogenous than monetary policy, with fiscal policy showing more low-frequency movements. See, among others, Fatás and Mihov (2001), von Jagen et al. (2001), Blanchard and Perotti (2002), Favero and Monacelli (2005), and Mountford and Uhlig (2009). Melitz (1997) in particular emphasizes the exogeneity of fiscal policy shock after removing the systematic reactions anticipated by debt and output as in our fiscal policy rule. Based on the slow-moving characteristic of fiscal policy and exogeneity of its disturbance, Muscatelli et al. (2002) analyze monetary and fiscal policy relationship by putting fiscal policy variable ahead of interest rate in their VAR model. A similar idea is also used in Kliem et al. (2016a,b) to justify their time-varying coefficient VAR model specification.

In line with the previous literature, we identify the current period fiscal policy disturbance $u_{f,t}$ as being most exogenous and the current monetary policy disturbance $u_{m,t}$ as responding to both fiscal policy disturbance $u_{f,t}$ and another orthogonal innovation $e_{m,t}$ that influences monetary policy disturbance $u_{m,t}$ but not fiscal policy disturbance $u_{f,t}$. For convenience, we label the orthogonal innovations $e_{m,t}$ and $e_{f,t}$ as proxies of monetary and fiscal policy shocks, respectively, in our subsequent discussions. We set the future fiscal policy factor innovation $v_{f,t+1}$ to be a linear combination of the current monetary and fiscal policy shocks, $e_{m,t}$ and $e_{f,t}$, and an additional shock $\varepsilon_{f,t+1}$ that affects both future fiscal and monetary policy innovations $v_{f,t+1}$ and $v_{m,t+1}$, but not the current fiscal and monetary disturbances, $u_{f,t}$ and $u_{m,t}$. We refer to $\varepsilon_{f,t+1}$ as the fiscal policy factor shock. Finally, the future monetary policy factor innovation $v_{m,t+1}$ is set as a linear combination of $e_{m,t}$ and $e_{f,t}$, $\varepsilon_{f,t+1}$ and one more shock $\varepsilon_{m,t+1}$ that affects only the future monetary factor innovation $v_{m,t+1}$. We call $\varepsilon_{m,t+1}$ monetary policy factor shock subsequently.

We may express the endogenous feedback channels that we defined earlier with the parameters in the covariance matrix P using more interpretable parameters of the at-impact response matrix Φ, viz., $\lambda, \phi_{11}, \phi_{12}, \phi_{21}, \phi_{22}$ and ϕ_{23}. The monetary policy self-feedback, i.e., the feedback from the current monetary policy disturbance $u_{m,t}$ to next period monetary policy factor innovation $v_{m,t+1}$, is given by $\phi_{21}\lambda + \phi_{22}\sqrt{1-\lambda^2}$. Similarly, the fiscal policy self-feedback from the current fiscal policy disturbance $u_{f,t}$ to next period fiscal policy innovation $v_{f,t+1}$ is given by ϕ_{11}. The monetary to fiscal cross-feedback, i.e., the feedback from $u_{m,t}$ to $v_{f,t+1}$, is given by $\phi_{11}\lambda + \phi_{12}\sqrt{1-\lambda^2}$, while the fiscal to monetary cross-feedback from $u_{f,t}$ to $v_{m,t+1}$ is given by ϕ_{21}.

We obtain the maximum likelihood estimates of the parameters $(\lambda, \phi_{11}, \phi_{12}, \phi_{21}, \phi_{22}, \phi_{23})$ in the identified at-impact impulse response matrix Φ from the maximum likelihood estimates of the parameters $(\rho_{u_m,u_f}, \rho_{u_m,v_m}, \rho_{u_m,v_f}, \rho_{u_f,v_m}, \rho_{u_f,v_f}, \rho_{v_m,v_f})$. We then estimate the structural equations in (7) using these estimates, and write out explicitly as

$$\begin{aligned}
u_{f,t} &= e_{f,t} \\
u_{m,t} &= 0.155 e_{f,t} + 0.988 e_{m,t} \\
v_{f,t+1} &= 0.175 e_{f,t} + 0.699 e_{m,t} + 0.693 \varepsilon_{f,t+1} \\
v_{m,t+1} &= 0.409 e_{f,t} + 0.809 e_{m,t} + 0.422 \varepsilon_{f,t+1} + 0.008 \varepsilon_{m,t+1}.
\end{aligned}$$

Under our identification scheme, we find the following. The monetary policy disturbance $u_{m,t}$ responds to monetary policy shock $e_{m,t}$ strongly but weakly to fiscal policy shock $e_{f,t}$. The fiscal policy factor innovation $v_{f,t+1}$ reacts substantially to monetary policy shock $e_{m,t}$ and fiscal policy factor shock $\varepsilon_{f,t+1}$, but weakly to fiscal policy shock $e_{f,t}$. We interpret a strong response of fiscal policy factor innovation to a monetary policy shock as a systematic response of fiscal policy stance for debt stabilization to a monetary policy surprise. The significant response of fiscal policy factor innovation $v_{f,t+1}$ to fiscal policy factor shock $\varepsilon_{f,t+1}$ reflects that a residual shock orthogonal to the policy disturbances plays a role in determining fiscal policy stance. The weak response of fiscal policy factor innovation $v_{f,t+1}$ to fiscal policy shock to $e_{f,t}$, which is in contrast to its strong response to monetary policy shock $e_{m,t}$, can be understood based on the argument that one-time exogenous fiscal policy surprises may not change fiscal authority's systematic behavior in the future. We observe that monetary policy factor innovation $v_{m,t+1}$ responds strongly to monetary policy shock $e_{m,t}$, moderately to fiscal policy and policy factor shocks, $e_{f,t}$ and $\varepsilon_{f,t+1}$, but does not react to monetary policy factor shock $\varepsilon_{m,t+1}$. This implies that very little is left unexplained in monetary policy factor innovation once the effects from the monetary and fiscal policy shocks and fiscal policy factor innovation are taken into account.

Subsequently we study the impulse responses of the monetary and fiscal policy factors in $w_t = (w_{m,t}, w_{f,t})$ to each of the four structural shocks in $\mathbf{e}_t = (e_{f,t}, e_{m,t}, \varepsilon_{f,t+1}, \varepsilon_{m,t+1})'$ driving the policy disturbances $u_t = (u_{f,t}, u_{m,t})$ and policy factor innovations $v_{t+1} = (v_{f,t+1}, v_{m,t+1})$. For the impulse response analysis, let $\Phi = (\Phi_1', \Phi_2')'$ and use this to write $v_{t+1} = \Phi_2 \mathbf{e}_t$. We then have

$$w_t = A^t w_0 + \sum_{k=0}^{t-1} A^k v_{t-k} = A^t w_0 + \sum_{k=0}^{t-1} A^k \Phi_2 \mathbf{e}_t$$

which shows how each of the four structural shocks in $\mathbf{e}_t$ propagates to the monetary and fiscal policy factors in w_t.

4.2 Impulse Response Analysis

In this section, we present impulse responses of monetary and fiscal policy factors to four orthogonal components, monetary and fiscal policy shocks $(e_{m,t}, e_{f,t})$ and policy factor shocks $(\varepsilon_{m,t+1}, \varepsilon_{f,t+1})$ specified in the previous section and conduct counterfactual impulse response analyses. Figures 2-6 plot impulse responses from the benchmark estimates and from shutting down one of three main interaction channels, dynamic interaction, endogenous feedback, or contemporaneous coordination subsequently. Specifically, given a one-unit orthogonal monetary (fiscal) policy shock at $t-1$,[20] we illustrate the transmission of a policy shock to a monetary (fiscal) disturbance at $t-1$, and to monetary and fiscal policy factors afterward. Given a positive policy shock, increases in monetary and fiscal policy factors represent that a central bank responds to inflation more aggressively, and fiscal authority puts more attention to debt stabilization supporting a conventional regime M (AM/PF). Similarly, for a negative policy shock, decreases in policy factors imply that policy authorities interact in inducing an alternative regime F (PM/AF).

Figure 2 traces the transmission of monetary and fiscal policy shocks to policy factors from $t-1$ to $t+1$ with a focus on effect of dynamic interaction channel. In each sub-figure, the black solid line is impulse response from our benchmark estimates, and the red dashed line is for when the dynamic interaction channel is partially shut down, a_{mf}=0 or a_{fm}=0. Most importantly, from black solid lines, we observe that monetary and fiscal policy shocks tend to induce changes in policy stances toward policy regimes consistent with existence of a unique equilibrium. Specifically, given a positive shock, monetary and fiscal policy stances become more active and passive, respectively, and with a negative policy shock, interaction between both policy authorities becomes more passive MP and active FP. In terms of effect size, monetary policy shock $e_{m,t-1}$ is more effective than fiscal policy shock in inducing changes in policy stances and their interaction quantitatively. When there is a positive one-unit $e_{m,t-1}$ shock, a monetary policy disturbance $u_{m,t-1}$ increases by 0.99 immediately without causing a change in fiscal policy disturbance. Based on our orthogonal component specification, the monetary factor innovation $v_{m,t}$, which equals to $w_{m,t}$ if assuming zero $w_{m,t-1}$ and $w_{f,t-1}$, increases by 0.81, and fiscal factor innovation $v_{f,t}$ increases by 0.70. Past policy shocks also contribute to the evolution of policy factors through the dynamic interaction of these factors, and the transmission of policy shocks from t to $t+1$ reveals this channel. Assuming

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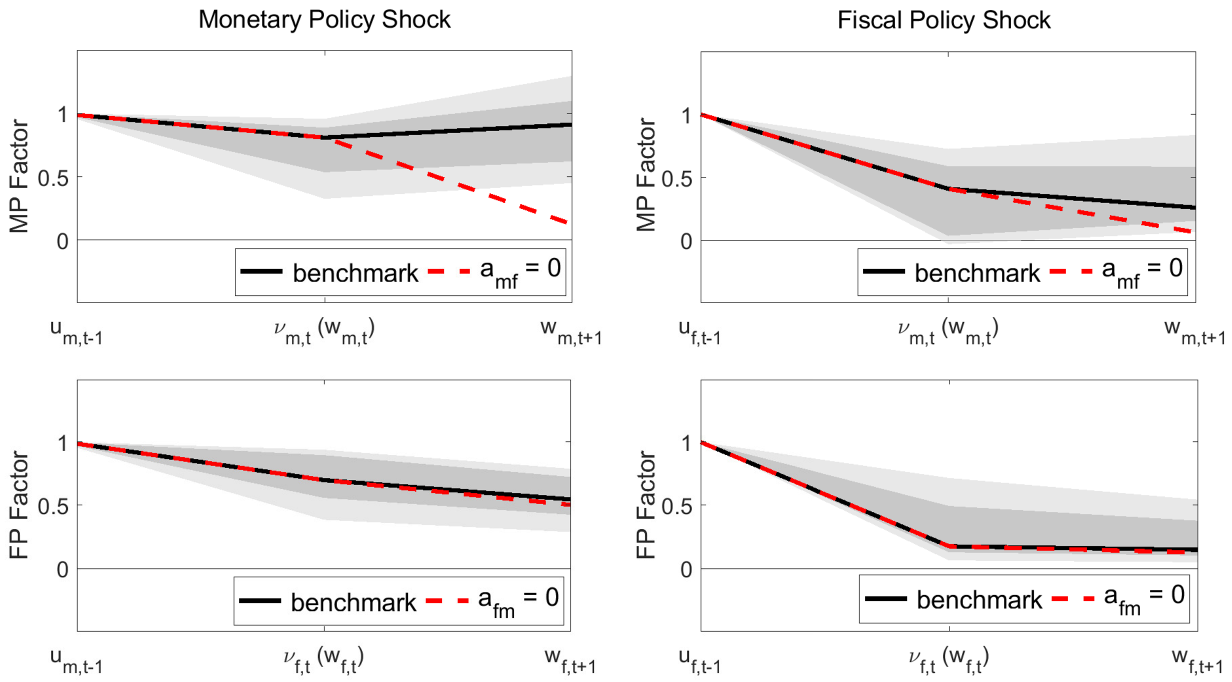
[20] One-unit shock stands for one standard deviation shock in our exercises.

Figure 2: Transmission of Policy Shocks to Policy Factors: Dynamic Interaction



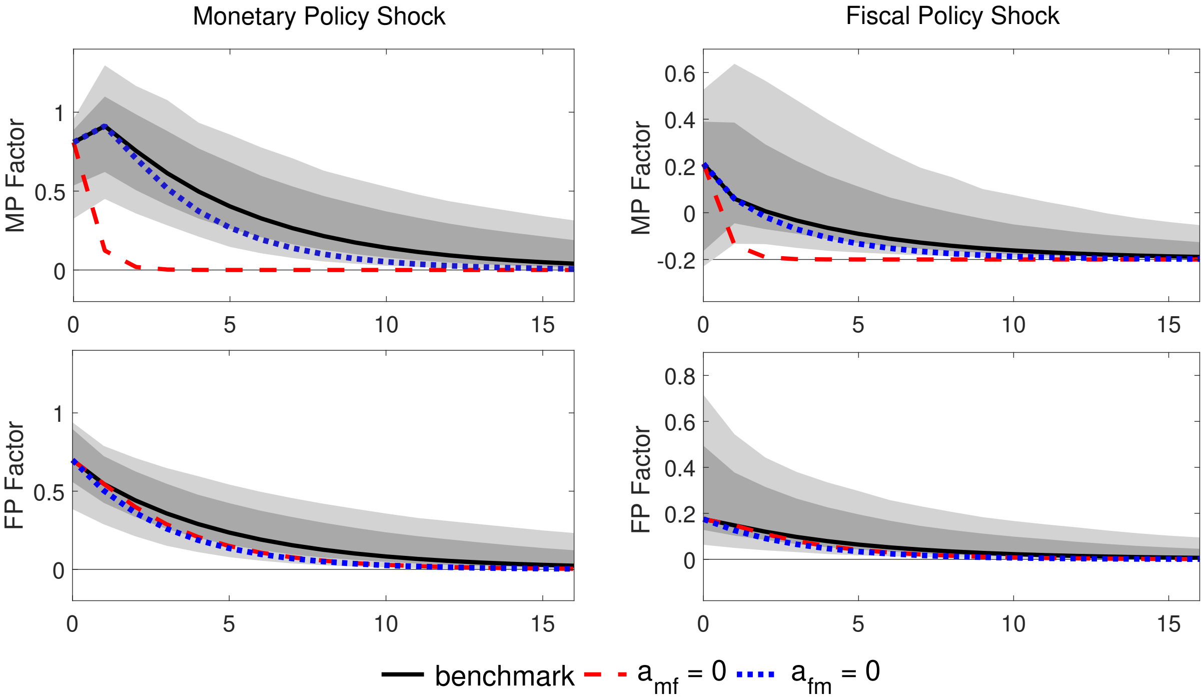
Notes: The Left and right panels present transmission of monetary and fiscal policy shocks at $t-1$, respectively, to policy factors. The black solid lines are benchmark dynamics of policy factors to a policy shock and dashed red lines are counterfactual dynamics of policy factors to a policy shock by shutting down dynamic interaction from current fiscal (monetary) policy factor to next period monetary (fiscal) policy factor for impulse response of monetary (fiscal) policy factor. The dark and light gray shaded areas, respectively, indicate 68% and 90% confidence intervals for the benchmark case.

zero factor innovations in the future, the position of monetary factor in the next period is the linear combination of current monetary and fiscal factors weighted by a_{22} and a_{21}, and similar to that of $w_{f,t+1}$. Quantitatively, we observe that a monetary policy shock generates a persistent and substantial impact on the evolution of both monetary and fiscal policy factors and therefore, their interaction. Our finding implies that with a positive MP shock, when monetary factor becomes more aggressive in controlling inflation, fiscal factor responds to a change in monetary factor in a way that pays more attention on debt stabilization.

In contrast to a monetary policy shock, a positive fiscal policy shock $e_{f,t-1}$ induces a relatively weak impact on policy interaction. A positive $e_{f,t-1}$ induces immediate impact on monetary policy disturbance at $t-1$ ($u_{m,t-1}$=0.15). One quarter after the shock, a fiscal policy factor increases by 0.17, implying that a one-unit fiscal policy shock results in a weak systematic response of fiscal authority. However, current monetary factor increases by 0.41 when this fiscal policy shock transmits to monetary policy factor through self-feedback and cross-feedback channels originated from policy disturbance u_{t-1} to $v_{m,t}$. We observe that the monetary policy authority's intention is significantly updated toward a more aggressive reaction to inflation upon a fiscal policy shock, even when an observed change in interest rate itself is not large ($u_{m,t}$=0.15).

Figure 2 demonstrates the quantitative importance of dynamic interaction from current fiscal factor to next period monetary factor a_{mf} in transmitting a policy shock to policy factors from time t to $t+1$. Red dashed lines in the left panel of Figure 2 show that if we suppress dynamic interaction from current fiscal factor to next period monetary factor (a_{mf}=0), the impulse response of monetary factor to a monetary policy shock quickly becomes zero. However, the evolution of fiscal factor is not influenced by shutting down the channel from current monetary factor to next period fiscal factor (a_{fm}=0). With a fiscal policy shock, we obtain similar results; only a_{mf} is influential to regime persistence.

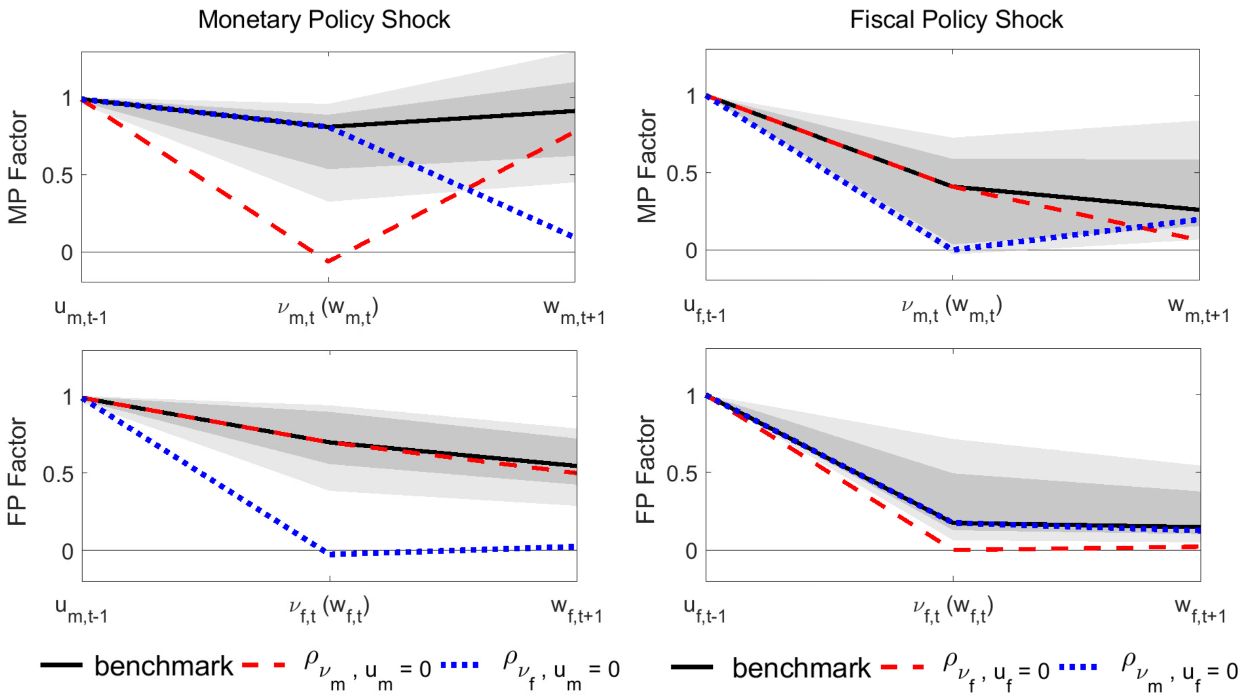
Figure 3: Impulse Responses of Policy Factors to Policy Shocks: Dynamic Interaction



Notes: The left and right panels present impulse responses of policy factors to monetary and fiscal policy shocks, respectively. Each subfigure includes a benchmark case (black solid line), and two counterfactual impulse responses: shutting down dynamic interaction from current fiscal policy factor to next period monetary policy factor (red dashed line) and from current monetary policy factor to next period fiscal policy factor (blue dashed-dotted line). The x-axis denotes quarters after a shock, and y-axis is for responses of policy factors. Dark and light shaded areas, respectively, denote 68% and 90% confidence intervals for the benchmark case.

We plot responses of monetary and fiscal policy factors over 16 quarters after a shock to quantify the impact of dynamic interaction channel on policy interaction. The left and right panels of Figure 3 present impulse responses of policy factors to monetary and fiscal policy shocks, respectively. The x-axis indicates periods after a monetary or fiscal policy shock, and the y-axis denotes responses of monetary and fiscal factors to a policy shock. The black solid line is for benchmark estimates, the red dashed line is for the case in which a_{mf}=0, and the blue dotted line is for when a_{fm}=0. We observe that a monetary policy shock induces substantial impacts on both factors and their coordination in the long-run; more active monetary policy stance and more passive fiscal policy stance. In the right panel, the fiscal policy shock also generates persistent coordination of monetary and fiscal factors. However, the magnitude of impact is relatively small, as a fiscal policy shock induces weak systematic responses to both monetary and fiscal policy rules. The persistence of policy cooperation comes from a_{mf}. Red dashed lines show that if a monetary authority does not systematically respond to past fiscal policy factor, policy coordination disappears quickly.

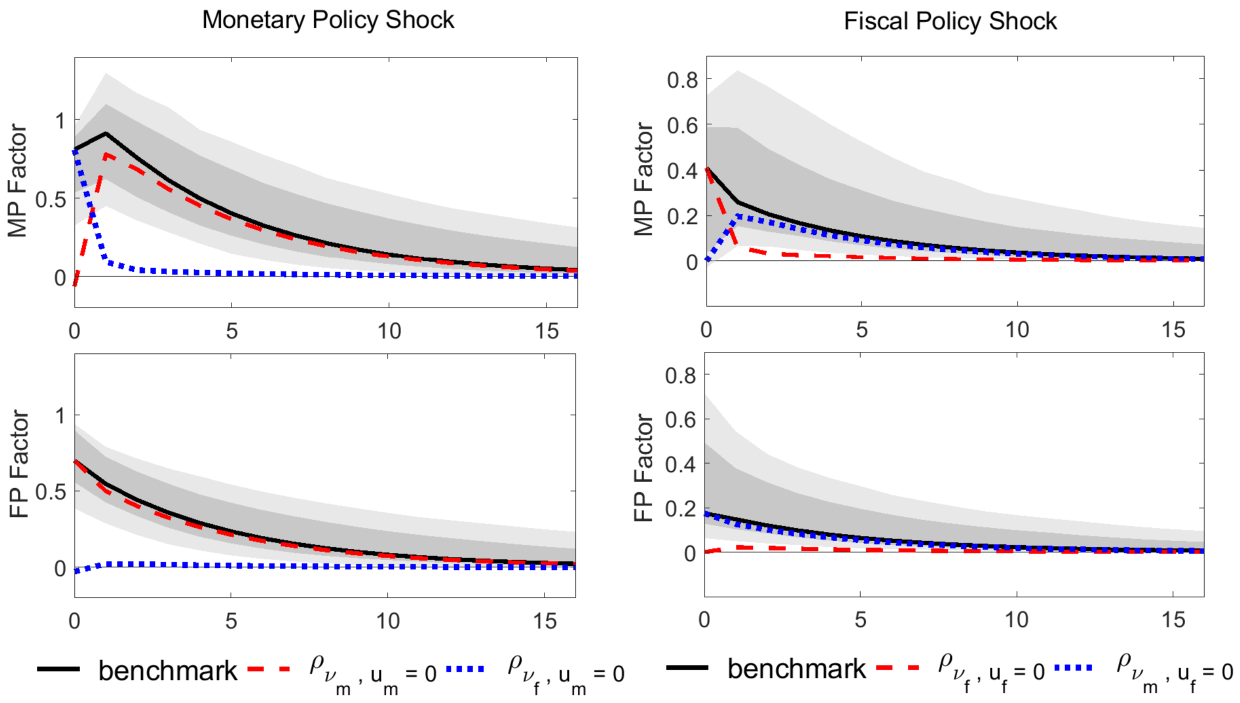
Figure 4: Transmission of Policy Shock to Policy Factors: Endogenous Feedback



Notes: The left and right panels present transmission of policy factors to monetary and fiscal policy shocks at $t-1$, respectively. The black solid lines are benchmark dynamics of policy factors to a policy shock, red dashed lines are counterfactual dynamics of policy factors to a policy shock by shutting down self-feedback channel, and blue dotted lines are when cross-feedback channel is ignored. The dark and light gray shaded areas, respectively, indicate 68 and 90% confidence intervals for the benchmark case.

Next, we quantify the impacts of self-feedback and cross-feedback on the transmission of policy shocks to policy factors in Figure 4. Given a policy shock at $t-1$, we plot responses of both policy factors at t and $t+1$ with a focus on effects of self-feedback and cross-feedback. We show that in the short-run, the evolution of monetary and fiscal factors depends on whether the fiscal authority adjusts its policy stance based on monetary and fiscal policy disturbances (ρ_{v_f,u_m} and ρ_{v_f,u_f}). Specifically, the left panel of Figure 4 shows that when fiscal authority ignores a monetary policy disturbance (ρ_{v_f,u_m}=0), effects of monetary policy shock on cooperative behavior between monetary and fiscal authorities disappear a quarter after impact. In the right panel, with a fiscal policy shock, if the fiscal authority does not react to its own disturbance (ρ_{v_f,u_f}=0), impacts of transmission of fiscal shock to policy interaction are attenuated. Therefore, in the short-run, the cooperative behavior of monetary and fiscal factors depends on whether fiscal authority adjusts its policy stance based on monetary and fiscal policy disturbances.

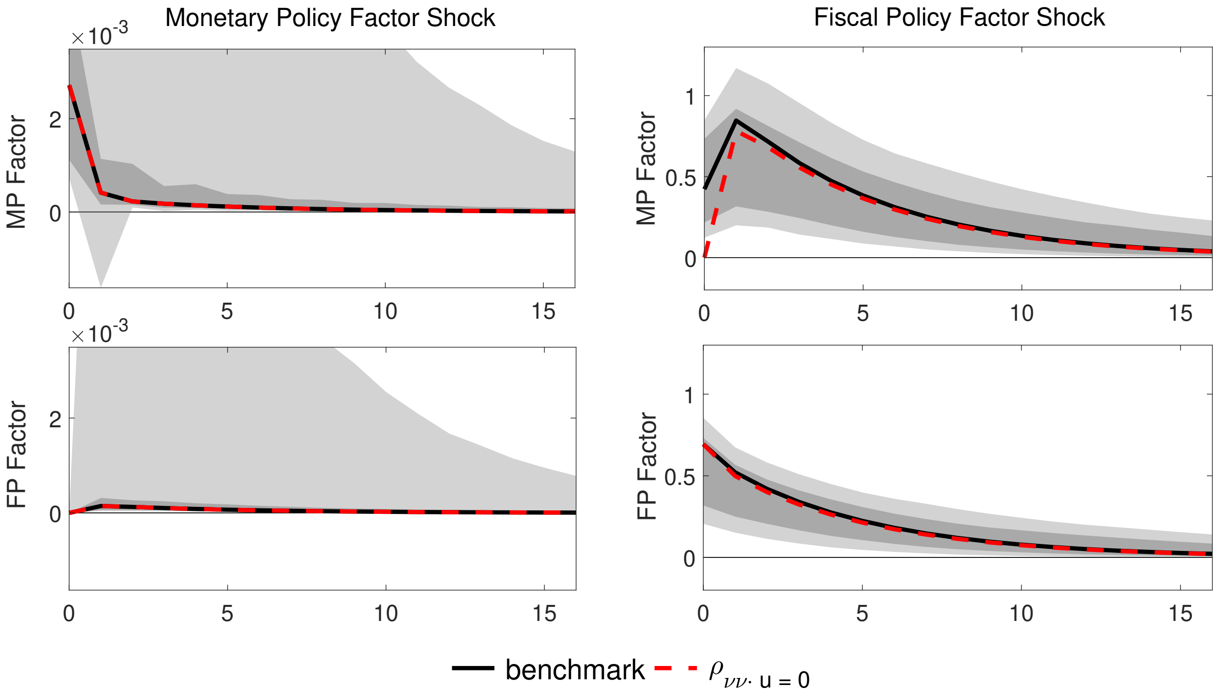
Figure 5: Impulse Responses of Policy Factors to Policy Shocks: Endogenous Feedbacks



Notes: The left and right panels present impulse responses of policy factors to monetary and fiscal policy shocks, respectively. Each subfigure includes a benchmark case (black solid line), and two counterfactual impulse responses: shutting down self-feedback from past own policy disturbance to current own policy factor (red dashed line) and cross-feedback from past one policy disturbance to current other policy factor (blue dashed-dotted line). The x-axis denotes quarters after a shock, and y-axis presents responses of policy factors. Dark and light shaded areas, respectively, present 68% and 90% confidence intervals for the benchmark case.

Figure 5 presents impulse responses of policy factors to monetary policy shock (in the left panel) and fiscal policy shock (in the right panel) over 16 quarters after a shock. As shown in blue dotted lines in the left panel, if a fiscal authority does not respond to a monetary policy shock, fiscal policy factor does not change significantly and the magnitude of response becomes negligible, even if dynamic interaction still works. Monetary policy factor responds to the monetary policy shock with a positive value in the first few quarters but becomes zero after a few quarters from the shock, i.e., without cross-feedback of fiscal policy stance to a monetary policy shock, the monetary policy shock is not transmitted to monetary policy factor persistently. Similarly, if the fiscal authority is inattentive to a monetary or fiscal policy shock and keeps its policy stance, coordination between two policy authorities is short-lasting as shown in red dashed lines in the right panel. Even if monetary policy authority does not update its policy stance immediately (ρ_{v_m,u_m}=0 or ρ_{v_m,u_f}=0), once the fiscal authority updates its stance, monetary policy stance is also adjusted with a lag and remains cooperative.

Figure 6: Impulse responses of Policy Factors to Policy Factor Shocks: Coordination at Impact



Notes: The left and right panels present impulse responses of policy factors to monetary and fiscal policy factor shocks, respectively. Each subfigure includes a benchmark case (black solid line), and a counterfactual impulse response by shutting down a contemporaneous policy coordination, $\rho_{vv\cdot u}$=0 (red dashed line). The x-axis denotes quarters after a shock, and y-axis presents responses of policy factors. Dark and light shaded areas, respectively, present 68% and 90% confidence intervals for the benchmark case.

Lastly, Figure 6 presents the impulse responses of policy factors with respect to policy factor shocks, η_{t-1}. We identify the fiscal factor shock $\eta_{f,t-1}$ to be quantitatively several order more important than its counterpart $\eta_{m,t-1}$. $\eta_{f,t-1}$, which is orthogonal to all policy shocks, influences both policy factor innovations and generates contemporaneous policy coordination. Our identification assumption implies that if monetary authority does not adjust its stance contemporaneously ($\rho_{vv\cdot u}$=0), the two authorities cannot achieve contemporaneous coordination in their stances. However, with a tight dynamic interaction between two policy authorities, we still observe a co-movement between monetary and fiscal policy factors in the long-run.

4.3 Policy Interaction in Frequency Domain

We also characterize the existence and strength of policy interaction from a different angle by measuring the coherence between policy factors in the frequency domain. Spectral density of monetary and fiscal policy factors w_t is

$$F_w(\lambda) = A^{-1}(e^{i\lambda})F_v(\lambda)A^{-1}(e^{i\lambda})^*, \quad \lambda \in [-\pi, \pi] \tag{8}$$

with F_v the spectral density of policy factor innovations v_t, and $*$ the adjoint operator. By *i.i.d.* assumption, $F_v = P_{vv}$ for all $\lambda \in [-\pi, \pi]$. Spectral density can be written as follows.

$$\begin{aligned} F_w(\lambda) &= \begin{pmatrix} F_{mm}(\lambda) & F_{mf}(\lambda) \\ F_{fm}(\lambda) & F_{ff}(\lambda) \end{pmatrix} \\ &\propto \begin{pmatrix} 1 - a_{ff}e^{i\lambda} & a_{mf}e^{i\lambda} \\ a_{fm}e^{i\lambda} & 1 - a_{mm}e^{i\lambda} \end{pmatrix} P_{vv} \begin{pmatrix} 1 - a_{ff}e^{-i\lambda} & a_{fm}e^{-i\lambda} \\ a_{mf}e^{-i\lambda} & 1 - a_{mm}e^{-i\lambda} \end{pmatrix} \end{aligned}$$

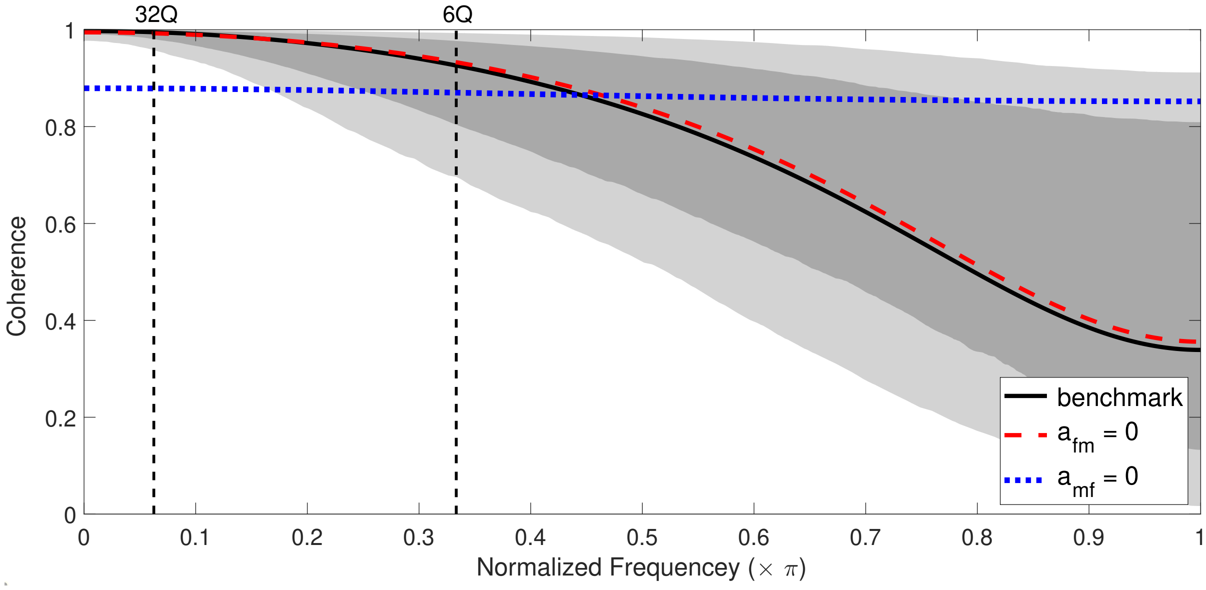
with a_{ij} the ij-th element in bivariate coefficient matrix A, and then coherence between two policy factors is measured by

$$\rho^2_{mf}(\lambda) = \frac{|F_{mf}(\lambda)|^2}{F_{mm}(\lambda)F_{ff}(\lambda)}$$

with $F_{mf}(\lambda)$ denoting the cross-spectral density. Measuring coherence in frequency domain provides additional information about the strengths of dynamic interaction, endogenous feedback, and contemporaneous coordination in monetary and fiscal policy interaction across different frequencies.

Figure 7 presents coherence between monetary and fiscal policy factors at frequency λ, being analogues to the R^2 statistic to capture the strength of co-movement between two policy factors. The benchmark result based on our baseline estimates shows that coherence between two policy factors captures the existence of an interaction between policy factors toward AM/PF or PM/AF across different frequencies, with stronger coherence at low-frequency and weaker coherence at higher frequencies. Especially at lower than and around business cycle frequency, we observe a strong coherence between two policy factors. Our empirical finding highlights the low-frequency interaction between monetary and fiscal policy factors. Kliem et al. (2016a,b) emphasize the importance of low-frequency relationships in the interaction between inflation and primary deficit to debt ratio. They capture the low-frequency interaction between two policy variables using the time-varying coefficient VAR model and calculate low-frequency interaction between two policy variables via spectral analysis. They also point out that changes of low-frequency interaction before and after the 1980s is induced by changes in systematic responses of policy variables from regime F to regime M. Tan (2019) considers a frequency domain analysis for policy interaction and finds that low-frequency domain is important to disentangle the ranking of preferred policy regime (regime M/F) in the U.S. data; in particular, low frequency is important to capture PM/AF regime. He finds that overall, both pre- and post-Volcker periods predominantly prefer regime F at frequencies

Figure 7: Coherence of Monetary and Fiscal Policy Factors: Dynamic Interaction



Notes: The graph presents magnitude-squared coherences of monetary and fiscal policy factors with and without dynamic interaction channel. The black solid line is for benchmark case, red dashed and blue dotted lines are for counterfactual analyses by shutting down dynamic interaction partially, a_{fm}=0 or a_{mf}=0. The dashed vertical lines indicate the normalized frequencies associated with 6 and 32 quarters. Dark and light shaded areas, respectively, present 68% and 90% confidence intervals for the benchmark case.

near the low end of the spectrum but assign more weights to regime M at higher frequencies.

Strong coherence between policy interaction at low-frequencies is well connected to fiscal policy specific characteristic: Blanchard and Perotti (2002) identify fiscal policy shock and discuss the high-frequency and low-frequency properties of fiscal variables. They demonstrate that high-frequency properties of fiscal variables capture a few extremely large quarterly changes in taxes and spending.[21] On the other hand, low-frequency, say decade-to-decade properties of fiscal variables may capture more systematic reactions to the economic status, including debt stabilization and discretionary concerns on the economy. Bianchi and Melosi (2014) demonstrate that current fiscal shock does not generate any impact to the economy under regime M. However, under an accumulated debt and uncertainty of debt financialization, private agents' belief to go back to regime M becomes pessimistic, and past fiscal shock finally impacts inflation dynamics and, therefore induces a change in monetary and fiscal policy stances.

We investigate the impacts of dynamic interaction, cross-feedback, and contemporaneous policy coordination to policy interaction via counterfactual analyses. For a counterfactual analysis, we impose a zero restriction on AR coefficient matrix A or a part of correlation coefficient matrix P_{vv}, as only AR and correlation coefficient matrices are relevant to the calculation of coherence based on the spectral density of w_t in equation 8. In Figure 7, the red dashed and blue dotted lines present

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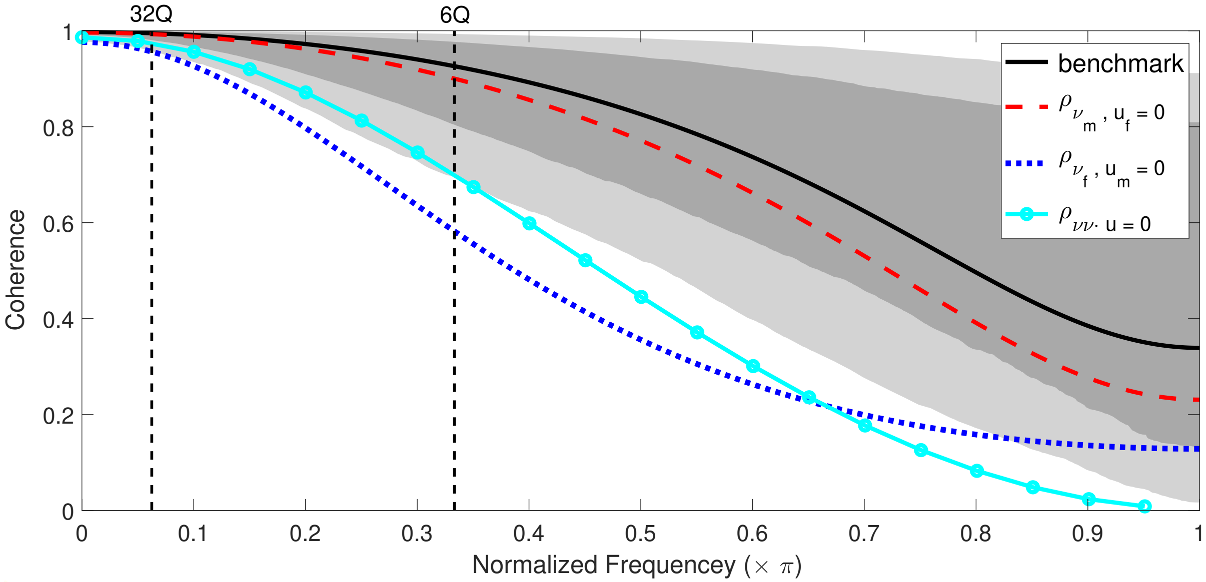
[21] For example, a large one-time payment of national Service Life Insurance benefits to the war veterans that caused an increase in net taxes in 1950:2, and the Korea War stands out in 1951:1, at the onset of the Korean War buildup.

Figure 8: Coherence of Monetary and Fiscal Policy Factors: Endogenous Feedback



Notes: The graph presents magnitude-squared coherences of monetary and fiscal policy factors with and without endogenous feedback channel. The black solid line is for benchmark case, red dashed and blue dotted lines are for counterfactual analyses by shutting down cross-feedback channel partially, ρ_{v_m,u_f}=0 or ρ_{v_f,u_m}=0. The cyan solid line with a round mark present a coherence when contemporaneous policy coordination is ignored. The dashed vertical lines indicate the normalized frequencies associated with 6 and 32 quarters. Dark and light shaded areas, respectively, present 68 and 90% confidence intervals for the benchmark case.

counterfactual coherence between policy factors when dynamic interaction from current fiscal policy factor to next period monetary policy factor, and from current monetary policy factor to next period fiscal policy factor are muted, respectively. We observe that without dynamic interaction from current fiscal policy factor to next period monetary policy factor, coherence between policy factors across frequencies flattens. Without dynamic interaction from current monetary policy factor to next period fiscal policy factor, changes in coherence are negligible, with a marginally improved coherence in high frequencies. This empirical finding hints that the existence of dynamic interaction emphasizes low-frequency interaction and mitigates the strength of the interaction in high frequencies.

Figure 8 shows the impacts of cross-feedback and contemporaneous policy coordination to coherence between monetary and fiscal policy factors. We observe that by suppressing contemporaneous coordination component, strength of the interaction between policy factors decreases cross all frequencies but much more in high-frequencies and that cross-equation feedback from past fiscal policy disturbance to current monetary policy factor improves the coherence between policy factors in higher frequencies. The existence of cross-equation feedback from past monetary policy disturbance to current fiscal policy factor improves coherence over all frequencies significantly but more in frequencies higher than business cycle. Results from frequency domain analysis are consistent with those from impulse response analysis, as we observe that dynamic interaction largely influences long-run cooperative policy behaviors while cross-feedback mainly influences policy coordination in the short-run.

5 Conclusion

Monetary and fiscal policy rules display strong dynamic interactions in the postwar U.S. data. Estimating the *endogenous* nature of the evolution of monetary and fiscal policy behaviors 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 coefficients and regime factor dynamics imply that monetary and fiscal policy behaviors fluctuate between two theoretically interpretable policy stances and that changes in one policy rule help to predict changes in the other policy rule. Second, a past monetary policy disturbance strongly influences current monetary and fiscal policy stances, and therefore their interaction. Lastly, a strong dynamic interaction between current fiscal policy stance and next period monetary policy stance generates persistent, long-run policy coordination inducing either regime M or regime F. These findings suggest that the novel regime switching methodology we employ provides useful tools to analyze and understand whether and how current monetary and fiscal policy stances influence future policy stances and therefore policy regimes.

The next step is to integrate our analysis of reduced form bivariate system of monetary and fiscal policy rules to a fully-specified dynamic stochastic general equilibrium model. In such a model, we will be able to provide clear structural meaning to the endogenous feedback. Each time, values of the realized shocks are reflected in the transition probabilities of policy regime changes, and agents use these time-varying probabilities to update their belief about the policy regime next period, and optimally make their consumption, saving and, investment decisions accordingly, which in turn has macroeconomic consequences. This requires solving a regime switching DSGE model with time-varying transition probabilities, which are given as a function of structural shocks. This is beyond the scope of our paper and left as future work.

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Appendix A: Robustness Checks

A.1: Comparisons of Alternative Model Specifications

We compare estimates from our baseline endogenous regime switching policy rules with those from alternative model specifications. We mainly consider impacts of specifications in policy regime factor and of smoothing component in policy rule. First three columns of Table 3 collect estimates of regime switching models with restricted policy regime factors (Models 1,2, and 3), and the last column presents estimates of an endogenous regime switching policy rules without smoothing components (Model 4). A specification of AR coefficient matrix A and correlation coefficient matrix P is essential to capture dynamics of policy regime factors through dynamic interaction, contemporaneous coordination, and endogenous feedback. For comparisons with our baseline specification, we impose restrictions on the A and P matrices: (1) equation by equation estimation of exogenous regime switching monetary and fiscal policy rules by imposing zeros on off-diagonals in the A matrix and zeros on the P matrix; (2) joint estimation of exogenous regime switching policy rules by imposing zeros on the P matrix; (3) joint estimation of endogenous regime switching model without cross-feedback channel by imposing zero restrictions on the P matrix partially. We observe that potential misspecification of policy regime factors may not alter interpretations of policy rule coefficients qualitatively; however, inferences on policy interaction are significantly different depending on specifications of A and P matrices. Therefore, restricted specifications of policy regime factors including a joint estimation of exogenous regime switching policy rules may limit the inference that we may draw on policy interaction.

We measure correlations between monetary and fiscal policy factors for three specifications with restricted A and P matrices. Correlations between policy factors from the equation by equation estimation of exogenous regime switching model (1) is zero, from the joint estimation of exogenous regime switching model (2) is 0.65, and from the endogenous regime switching model without cross-feedback (3) is 0.81 that are significantly smaller than one from our baseline model, 0.98. By allowing less restricted A and P matrices, correlations between monetary and fiscal policy factors become larger, implying stronger co-movement between two policy authorities. For a better understanding of policy interactions, therefore, we need to allow generalized A and P matrices and let data tell us how two policy authorities have interacted.

Lastly, we turn to an impact of smoothing components in policy rules. As shown in the last column of Table 3, when zero restrictions are imposed on the smoothing components in both monetary and fiscal policy rules, estimates differ significantly from the baseline estimates. We observe that self-feedback becomes strong, but cross-feedback is muted; ignoring smoothing components may generate persistence of policy disturbances and make self-feedback dominates the dynamic of policy regime factors. In terms of estimates of policy rule coefficients, without a smoothing component in monetary policy rule, we still observe two interpretable monetary policy stances, but differences between policy stances are less distinguishable. For the fiscal policy rule without a smoothing component, we can obtain distinguishable two regimes for responses to output and government spending but not for responses to debt. We observe a significant deterioration in log likelihood of each restricted model, especially of a model without smoothing components compared to one from our baseline specification.

Table 3: Comparisons of Alternative Model Specifications

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	90% CI	Estimate	90% CI	Estimate	90% CI	Estimate	90% CI
ψ_m	2.256	[-2.041,8.326]	3.829	[0.297,9.985]	0.724	[-1.931,2.537]	5.994	[-8.272,9.994]
ψ_f	-2.080	[-3.892,-1.330]	-2.172	[-3.140,-1.461]	-2.898	[-5.992,-1.742]	-4.038	[-9.991,9.993]
a_{mm}	0.963	[0.627,0.994]	0.694	[0.569,0.944]	0.936	[0.920,0.952]	0.994	[0.642,0.994]
a_{fm}	-	-	0.000	[-0.031,0.008]	0.496	[0.246,1.246]	0.000	[-0.062,0.219]
a_{mf}	-	-	1.809	[0.418,3.996]	0.000	[-0.109,0.125]	0.000	[-0.813,0.359]
a_{ff}	0.772	[-0.384,0.929]	0.776	[0.479,0.878]	0.245	[-0.724,0.620]	0.995	[-0.107,0.995]
ρ_{u_m,u_f}	-	-	-	-	-	-	0.454	[0.344,0.547]
ρ_{v_m,u_m}	-	-	-	-	0.749	[0.249,0.968]	0.701	[-0.746,0.983]
ρ_{v_f,u_m}	-	-	-	-	-	-	-0.010	[-0.824,0.758]
ρ_{v_m,u_f}	-	-	-	-	-	-	0.326	[-0.743,0.900]
ρ_{v_f,u_f}	-	-	-	-	0.239	[-0.823,0.989]	0.022	[-0.654,0.752]
ρ_{v_m,v_f}	-	-	-	-	-	-	-0.006	[-0.863,0.870]
$\rho_{vv\cdot u}$	-	-	-	-	-	-	0.169	[-0.127,0.632]
$\alpha_{\rho,0}$	0.780	[0.749,0.811]	0.785	[0.754,0.817]	0.725	[0.693,0.756]	-	-
$\alpha_{\rho,1}$	0.654	[0.561,0.717]	0.696	[0.649,0.727]	0.753	[0.722,0.784]	-	-
$\alpha_{c,0}$	2.233	[1.733,2.764]	2.444	[1.913,2.929]	1.635	[1.260,2.229]	1.377	[1.190,1.690]
$\alpha_{c,1}$	2.332	[1.191,3.652]	1.994	[1.197,2.837]	1.396	[0.193,2.301]	3.469	[-0.781,3.852]
$\alpha_{\pi,0}$	0.561	[0.467,0.639]	0.514	[0.420,0.607]	0.631	[0.568,0.693]	0.792	[0.761,0.807]
$\alpha_{\pi,1}$	1.477	[0.648,1.695]	1.533	[1.307,1.705]	1.786	[1.443,1.974]	1.101	[0.820,1.413]
$\alpha_{y,0}$	0.576	[0.435,0.701]	0.609	[0.484,0.734]	0.447	[0.322,0.556]	0.347	[0.284,0.409]
$\alpha_{y,1}$	-0.188	[-0.414,0.234]	-0.262	[-0.426,-0.075]	-0.025	[-0.212,0.163]	0.011	[-0.239,0.581]
α_η^π	0.089	[0.042,0.152]	0.092	[0.029,0.154]	0.099	[0.052,0.162]	-0.061	[-0.217,0.095]
α_η^y	0.058	[-0.005,0.120]	0.071	[0.009,0.134]	0.062	[-0.001,0.109]	-0.139	[-0.279,-0.014]
σ_m	0.459	[0.413,0.491]	0.456	[0.409,0.487]	0.455	[0.409,0.487]	1.002	[0.893,1.080]
$\beta_{\rho,0}$	0.139	[0.030,0.311]	0.140	[0.015,0.328]	0.159	[0.034,0.533]	-	-
$\beta_{\rho,1}$	0.948	[0.933,0.964]	0.948	[0.932,0.964]	0.952	[0.936,0.967]	-	-
$\beta_{c,0}$	3.366	[3.241,3.538]	3.343	[3.218,3.515]	3.340	[3.090,3.526]	4.355	[2.980,4.644]
$\beta_{c,1}$	2.017	[1.251,2.853]	2.037	[1.334,2.803]	1.967	[1.092,2.873]	1.176	[1.129,1.316]
$\beta_{b,0}$	0.085	[0.085,0.085]	0.085	[0.085,0.085]	0.090	[0.090,0.090]	-0.012	[-0.012,-0.012]
$\beta_{b,1}$	0.127	[0.111,0.158]	0.127	[0.111,0.158]	0.139	[0.124,0.171]	-0.012	[-0.012,-0.012]
$\beta_{y,0}$	0.329	[0.298,0.384]	0.326	[0.294,0.388]	0.317	[0.254,0.379]	0.336	[-0.164,0.586]
$\beta_{y,1}$	0.294	[0.169,0.435]	0.291	[0.166,0.431]	0.297	[0.156,0.453]	0.080	[0.064,0.111]
$\beta_{g,0}$	-0.343	[-0.343,-0.343]	-0.343	[-0.343,-0.343]	-0.367	[-0.367,-0.367]	-0.206	[-0.206,-0.206]
$\beta_{g,1}$	-0.064	[-0.252,0.107]	-0.071	[-0.243,0.085]	-0.076	[-0.278,0.111]	0.357	[0.357,0.357]
β_η^y	0.023	[0.007,0.038]	0.023	[0.008,0.039]	0.024	[0.008,0.039]	-0.084	[-0.116,-0.053]
σ_f	0.137	[0.121,0.153]	0.137	[0.121,0.153]	0.137	[0.121,0.153]	0.258	[0.242,0.273]
log likelihood	-84.193		-81.233		-75.079		-332.516	

Notes: Table 3 collects estimates and 90% confidence intervals of four alternative model specifications; (1) equation by equation estimation of an exogenous regime switching model, (2) joint estimation of an exogenous regime switching model, (3) joint estimation of an endogenous regime switching model without cross-feedback, and (4) joint estimation of an endogenous regime switching model without smoothing components in policy rules. All missing values (-) are zeros.

A.2: Regime Invariant Coefficient Specification

As a robustness check, we consider which policy coefficients should be specified as switching coefficients based on 90% confidence intervals of regime dependent coefficients in our baseline model that allows all policy coefficients are regime dependent. We observe that differences between regime dependent smoothing coefficient α_ρ and constant term α_c in the monetary policy rule and regime dependent coefficients on government spending β_g and the output gap β_y in the fiscal policy rule are statistically insignificant at 90% confidence. Therefore, we consider those four coefficients as regime invariant policy coefficients and re-estimate our model. Table 4 presents the estimates and 90% confidence intervals of the model with regime-invariant coefficients, and estimates and interpretations from our baseline specification and a parsimonious specification are generally consistent.

Table 4: Estimation with Regime Invariant Coefficient Specification

Monetary Policy			Fiscal Policy			Regime Factor Dynamics		
Parameter	Estimate	90% CI	Parameter	Estimate	90% CI	Parameter	Estimate	90% CI
α_ρ	0.724	[0.701,0.748]	$\beta_{\rho,0}$	0.114	[0.005,0.372]	ψ_m	0.844	[-0.382,2.329]
			$\beta_{\rho,1}$	0.955	[0.939,0.971]	ψ_f	-2.453	[-3.766,-1.735]
α_c	1.833	[1.434,2.204]	$\beta_{c,0}$	3.301	[3.144,3.488]	a_{mm}	0.226	[-0.032,0.578]
			$\beta_{c,1}$	2.358	[1.827,2.929]	a_{fm}	0.054	[0.054,0.085]
$\alpha_{\pi,0}$	0.586	[0.515,0.648]	$\beta_{b,0}$	0.082	[0.082,0.082]	a_{mf}	1.078	[0.554,1.476]
$\alpha_{\pi,1}$	1.639	[1.483,1.764]	$\beta_{b,1}$	0.193	[0.162,0.224]	a_{ff}	0.719	[0.594,0.844]
$\alpha_{y,0}$	0.422	[0.328,0.516]	β_y	0.340	[0.293,0.402]	$\rho_{u_m u_f}$	0.128	[0.003,0.253]
$\alpha_{y,1}$	-0.042	[-0.199,0.114]				$\rho_{v_m u_m}$	0.838	[0.375,0.964]
α_η^π	0.125	[0.047,0.204]	β_g	-0.309	[-0.324,-0.293]	$\rho_{v_f u_m}$	0.701	[0.369,0.943]
α_η^y	0.0467	[-0.0158,0.1092]				$\rho_{v_m u_f}$	0.329	[-0.091,0.651]
σ_m	0.467	[0.404,0.498]	β_η^y	0.026	[0.010,0.041]	$\rho_{v_f u_f}$	0.156	[0.074,0.638]
			σ_f	0.137	[0.121,0.153]	$\rho_{v_m v_f}$	0.938	[0.698,0.975]
						$\rho_{vv\cdot u}$	0.336	[0.085,0.548]
log likelihood	-68.442							

A.3: The Presence of 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 zero lower bound (ZLB) period, 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.

In our framework, two possible approaches have been suggested to handle the issues related to the ZLB of interest rates when we identify the underlying policy regimes covering the ZLB period. The first feasible approach is using an econometric technique proposed in Gonzalez-Astudillo (2018). He considers a joint estimation of monetary and fiscal policy rules that links the switching coefficients of the Taylor rule regression to the switching of the fiscal policy rule coefficients to identify underlying monetary policy stances in the presence of the ZLB period. 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. The technique and the idea from the first approach are possibly implemented to our joint estimation of monetary and fiscal policy rules, however we leave the extension of our baseline specification with a censored specification for a future work. For a robustness check, 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 $t = 2009:1$. Table 5 presents estimates of our baseline model using a new policy rate i_t^*, and the estimation result and identified policy regime are consistent with ones from the baseline estimation.

Table 5: Estimates using Shadow Rate from 2009:1

Monetary Policy			Fiscal Policy			Regime Factor Dynamics		
Parameter	Estimate	90% CI	Parameter	Estimate	90% CI	Parameter	Estimate	90% CI
$\alpha_{\rho,0}$	0.790	[0.759,0.821]	$\beta_{\rho,0}$	0.126	[0.008,0.329]	ψ_m	0.725	[-0.525,2.225]
$\alpha_{\rho,1}$	0.790	[0.743,0.833]	$\beta_{\rho,1}$	0.944	[0.925,0.962]	ψ_f	-2.554	[-4.117,-1.659]
$\alpha_{c,0}$	1.658	[1.043,2.281]	$\beta_{c,0}$	3.301	[3.192,3.426]	a_{mm}	-0.169	[-0.419,0.518]
$\alpha_{c,1}$	1.078	[-0.146,2.078]	$\beta_{c,1}$	1.845	[1.345,2.507]	a_{fm}	0.054	[0.007,0.101]
$\alpha_{\pi,0}$	0.595	[0.512,0.666]	$\beta_{b,0}$	0.0865	[0.085,0.085]	a_{mf}	1.336	[0.523,1.961]
$\alpha_{\pi,1}$	1.875	[1.632,2.123]	$\beta_{b,1}$	0.121	[0.102,0.138]	a_{ff}	0.777	[0.675,0.847]
$\alpha_{y,0}$	0.618	[0.462,0.774]	$\beta_{y,0}$	0.342	[0.296,0.381]	$\rho_{u_m u_f}$	0.196	[0.072,0.329]
$\alpha_{y,1}$	-0.010	[-0.260,0.240]	$\beta_{y,1}$	0.291	[0.182,0.416]	$\rho_{v_m u_m}$	0.807	[0.305,0.967]
α_η^π	0.082	[0.020,0.145]	$\beta_{g,0}$	-0.321	[-0.321,-0.321]	$\rho_{v_f u_m}$	0.634	[0.332,0.948]
α_η^y	0.061	[-0.002,0.123]	$\beta_{g,1}$	-0.020	[-0.160,0.081]	$\rho_{v_m u_f}$	0.445	[0.016,0.768]
σ_m	0.489	[0.426,0.522]	β_η^y	0.020	[0.004,0.036]	$\rho_{v_f u_f}$	0.205	[0.084,0.745]
			σ_f	0.138	[0.124,0.147]	$\rho_{v_m v_f}$	0.834	[0.621,0.983]
						$\rho_{vv \cdot u}$	0.298	[0.015,0.667]
log likelihood	-78.847							

Appendix B: Adaptive LASSO Method

Tibshirani (1996) proposes the LASSO method, which adds a penalty for model complexity (L_1-regularization) to OLS regression, yielding solutions that are sparse in terms of the regression coefficients. To be specific, let y denote either monetary policy factor or fiscal policy factor and X the set of potential candidate variables.[22] Then the LASSO estimator is given as

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

where λ is a nonnegative regularization parameter and N the dimension of X. It is well known that the solution to LASSO objective function is nonlinear and no closed form solution exists. Among several algorithms proposed for obtaining LASSO solution, we use the maximization algorithm implemented in McIlhagga (2016) to solve the LASSO. To ensure that we select a model that gives a balance between the goodness of fit and the complexity of the model, we use the Bayesian Information Criterion (BIC). Specifically, we choose the regularization parameter λ which minimizes the BIC given by $BIC(\lambda) = \| y - X\beta(\lambda) \|^2 + \log(n)\sigma_\epsilon^2 df(\lambda)$, where $df(\lambda)$ the degree of freedom given by the number of nonzero coefficients, n is the number of observations, and σ_ϵ^2 represents the residual variance of a low-bias model which is equivalent to a ridge regression when its penalty term goes zero. Using the numerical algorithm and BIC, we can obtain 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.

Fan and Li (2001) conjecture the lack of oracle property in the LASSO estimates, and 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 replaces the L_1-regularization in the LASSO objective function with a properly chosen weighted L_1-penalty term, i.e.,

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

where λ is a nonnegative regularization parameter, N the dimension of X, and $|\hat{\beta}_i(\delta)|$ is the adaptive weight given by the ridge regression estimate $\hat{\beta}_i$ obtained with a properly chosen ridge regression parameter δ.[23] We choose the ridge regression parameter δ and the regularization parameter λ, which minimize the BIC, and select the corresponding variables as the predictors for each of our target variables, monetary and fiscal policy factors.

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[22] y is the demeaned series and X is the set of standardized series. We transform X properly to ensure stationarity before standardization. Required transformation is done by using the transformation code provided in McCracken and Ng (2020) online appendix.

[23] Due to the possibility of having a high level of collinearity among the large number of predictors considered in our analysis, we use the ridge regression estimate which is more stable than the OLS estimate.