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

Yoosoon Chang[†]
Department of Economics
Indiana University

Boreum Kwak[‡]
Martin-Luther University Halle-Wittenberg
and Halle Institute for Economic Research

Shi Qiu[§]
School of Economics
Fudan University

April 10, 2021

Abstract

We investigate U.S. monetary and fiscal policy interactions in a regime-switching model of monetary and fiscal policy rules where policy mixes are determined by a latent bivariate autoregressive process consisting of monetary and fiscal policy regime factors, each determining a respective policy regime. Both policy regime factors receive feedback from past policy disturbances, and interact contemporaneously and dynamically to determine policy regimes. We find strong feedback and dynamic interaction between monetary and fiscal authorities. The most salient features of these interactions are that past monetary policy disturbance strongly influences both monetary and fiscal policy regimes, and that monetary authority responds to past fiscal policy regime. We also find substantial evidence that the U.S. monetary and fiscal authorities have been interacting: central bank responds less aggressively to inflation when fiscal authority puts less attention on debt stabilization, and vice versa.

JEL Classification: E52, E63, C13, C32

Key words and phrases: monetary and fiscal policy rules, endogenous regime switching, joint estimation, policy interactions, feedback channels.

*We are very grateful to Eric M. Leeper for many insightful comments which significantly improved earlier versions of the paper, and also to Joon Y. Park, Yongok Choi, Fei Tan, Alexander Kriwoluzky and Jihyun Kim for numerous discussions and invaluable suggestions. We thank the participants at 2015 Midwest Econometrics Group Meetings, 2016 St. Louis Fed Econometrics Workshop, 2016 IAAE Meeting, 2016 Asian Meeting of Econometric Society, 2016 CFE-CMStatistics, 2016 IWH-CIREQ-GW Macroeconometric Workshop, 2018 Taiwan Econometric Society Meeting, 2017 SNDE conference and the seminar participants at UC Santa Barbara, Harvard-MIT, NYU, Columbia, Texas A&M, University of Cincinnati, Sungkyunkwan University, Tsinghua University, Fudan University, University of Kentucky, Seoul National University, Australian National University, University of Sydney, NY Fed, Bank of Korea, Bank of Italy, BI Norwegian Business School, Banque de France, Reserve Bank of Australia, and Norges Bank for their helpful comments and feedback.

[†]Corresponding author. Bloomington, IN 47405-7104, USA. E-mail: yoosoon@indiana.edu.

[‡]06108 Halle (Saale), Germany. E-mail: Boreum.Kwak@iwh-halle.de.

[§]Shanghai, 200433, China. E-mail: shiqiu.iub@gmail.com.

1 Introduction

The global financial crisis and Great Recession have generated growing interest in 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] Theory points to two distinct, but equally plausible, policy mixes that permit monetary and fiscal policies to accomplish these tasks. The conventional policy mix features a central bank that stabilizes inflation by systematically raising nominal interest rates more than one-for-one with inflation and a fiscal authority that adjusts taxes or government spending to assure fiscal solvency. An alternative policy mix reverses the policy roles: fiscal policy determines the price level, and monetary policy stabilizes debt.[2] Because these two policy mixes imply completely different transmission channels of policy shocks, it is important to understand how monetary and fiscal policy interacts. Answers to this question are essential in evaluating the effectiveness of policy choices.

While economic theory emphasizes how monetary and fiscal regimes must coordinate to determine the price level uniquely, early empirical studies in monetary and fiscal policy interactions tend to focus on dynamic patterns of correlation among *policy variables*.[3] 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 dynamic stochastic general equilibrium (DSGE) model (Favero and Monacelli (2005), Davig and Leeper (2006b), Chung et al. (2007), Bianchi (2012), Bianchi and Ilut (2017), and Gonzalez-Astudillo (2018)). Most existing works, however, assume that policy regimes change exogenously. Such exogenous switching models are unable to meaningfully answer why regime changes occur and how changes in one policy regime affect those of the other. This limits the inferences we can draw about policy interactions since monetary and fiscal policies respond to state of economy purposefully and may influence each other.

In this paper, we adopt an alternative regime-switching model for monetary and fiscal policy rules where changes in monetary and fiscal policy regimes are allowed to interact with each other and receive feedback from previous policy actions. This framework allows us to construct novel and interpretable measures of policy coordination between the two authorities. And our work contributes to empirical studies on policy interaction by providing fresh and substantial empirical evidence on monetary and fiscal policy interactions.

To this end, we jointly estimate the regime-switching monetary and fiscal policy rules in a bivariate system, and infer the interactions of monetary and fiscal policies. Conditional on a regime,

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

[2] By making primary surpluses insensitive to debt, the price level must adjust to equate the real value of outstanding debt to the expected discounted present value of current and future primary surpluses. Debt stabilization is achieved as monetary policy passively permits necessary changes in the current and future price levels by responding weakly to current inflation.

[3] For example, King and Plosser (1985), Melitz (1997, 2000), von Jagen et al. (2001), Muscatelli et al. (2002), and Kliem et al. (2016a,b)

choice of policy instrument in a policy rule depends on policy smoothing, systematic responses to policy target variables, as well as a policy disturbance that reflects the non-target information. More specifically, we assume a Taylor-type monetary policy rule in which the nominal interest rate depends on lagged interest rate, inflation, output gap and monetary policy disturbance. Similarly, we consider a fiscal policy rule that adjusts tax revenues in response to government purchases, real market value of outstanding government debt, output gap and fiscal policy disturbance with policy smoothing.

A policy regime is determined by a latent policy regime factor and a threshold, and policy coefficients in each policy rule are specified as functions of the respective policy regime. The monetary policy regime is *hawkish* if the monetary regime factor is above the monetary threshold and is *dovish* if otherwise. With a hawkish regime, monetary authority raises interest rates more than one-for-one with inflation. Similarly, we adopt the notion of "deficit hawk" and say the fiscal policy regime is *hawkish* if the fiscal regime factor is above the fiscal threshold. In a hawkish regime, fiscal policy raises tax revenues aggressively to stabilize the real value of debt. Two policy factors jointly determine a monetary and fiscal policy mix/combination. For notational convenience, we simply label the policy combination of a hawkish monetary regime and a hawkish fiscal regime as a *doubly-hawkish* mix, and analogously the mix of a dovish monetary regime and a dovish fiscal regime as a *doubly-dovish* mix. In our specification, a strong positive correlation between monetary and fiscal policy factors imply that the monetary-fiscal policy combination switches mostly between the doubly-hawkish and the doubly-dovish mixes.

To the best of our knowledge, this is the first paper that elicits information about monetary and fiscal policy interactions from the joint dynamics of the latent policy factors that determine policy regimes. Our model has two unique features to make it possible. First, we assume the vector of latent policy factors to evolve as a stationary vector autoregressive process to allow monetary and fiscal policy factors to interact dynamically and contemporaneously. The autoregressive coefficient matrix characterizes the *dynamic policy interaction* between the policy factors. Second, policy factors are allowed to receive feedback from past policy disturbances which may represent policy makers' considerations beyond what is already reflected in target variables. Mechanically, the innovations that drive policy factors in the current period are correlated with the past policy disturbances, and this correlation produces the dynamic feedback effects. The dynamic feedback establishes a channel through which additional information on the economy relevant for policy regime changes is carried over to the policy factors.[4] Therefore, it renders the switches of policy regimes consistent with the common perspective on purposeful policy behaviors. For this reason, we regard the feedback from policy disturbances to policy factors as *endogenous*.

Our bivariate system of policy rules features two types of dynamic feedback channels, namely, self-feedback and cross-feedback. The self-feedback occurs within each policy rule, channeling information from its own past policy disturbance to its current policy factor. For example, when

[4] Gonzalez-Astudillo (2018) shows that a strong interdependence between monetary and fiscal policies improves the identification of prevalent monetary policy regime that is potentially unidentified under the zero lower bound.

the monetary policy sets the interest rate above the level implied by target variables, we have a positive monetary policy disturbance, which predicts future changes in the monetary policy regime factor and the monetary regime. The cross-feedback occurs across policy rules, either from past monetary policy disturbance to current fiscal policy factor, or from past fiscal policy disturbance to current monetary policy factor. It allows us to analyze, for example, whether and how a change in monetary regime may lead to a switching in the fiscal regime. This is particularly relevant since many believe that central banks take into account the stance of fiscal policy in making its policy choices.[5] Note that self-feedback can be obtained by implementing the univariate endogenous regime-switching model of Chang et al. (2017) equation-by-equation for each policy rule. However, the cross-feedback channel can be created only when we consider two policy rules together with joint policy factor dynamics as in our bivariate system.

Policy interactions in our model are also driven by the contemporaneous policy interaction arising from correlation between the two policy factor innovations. As discussed earlier, policy factor innovations receive feedback from past policy disturbances. It is therefore meaningful to devise a measure of contemporaneous policy interaction net of feedback effects. To this end, we purge out feedback effects from the policy factor innovations and measure the policy interaction taking place only in the current period by the correlation between residual parts of the policy factor innovations. We call this net measure of policy interaction the *contemporaneous policy coordination*. Dynamic interaction, endogenous feedback channels, and contemporaneous policy coordination between policy factors measure the degree of monetary and fiscal policy coordination. These new measures are critically relevant for understanding the nature of the changes in policy regimes and origins of policy interactions. In the paper, we measure these three novel channels of monetary and fiscal policy interactions and provide economic and econometric interpretations.

We estimate our model by the maximum likelihood (ML) method using the filter developed by Chang et al. (2020) for regime-switching models with multiple regime factors. The ML estimates report two distinct and interpretable policy regimes in monetary and fiscal policy rules and strong self-feedback and cross-feedback. We find that the current monetary policy disturbance has sizable effects on the switching of next period monetary policy regime through self-feedback, as well as on the change in the next period fiscal policy regime through cross-feedback. On the other hand, a fiscal policy disturbance yields much weaker feedback effects on both monetary and fiscal regimes. Moreover, we report strong dynamic interaction between monetary and fiscal policies. Our measure of dynamic interaction between policy factors suggests that a change in fiscal policy regime leads to switching in the monetary policy regime. Interestingly, the dynamic interaction and feedback do not account for all comovements in regime shifts. In addition to these dynamic effects, we also find substantial contemporaneous policy coordination between the two policy factors.

In addition to standard time-domain analyses, we perform frequency domain analyses to scru-

[5] 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 in reaching debt-management decisions.

tinize the impacts of endogenous feedback, dynamic interaction and contemporaneous policy coordination channels on interaction between the two policy factors. Our results reveal substantial coherence between the policy factors across all frequencies. In particular, we observe very strong coherence between monetary and fiscal policy factors at lower than and around business cycle frequencies that supports the importance of low-frequency policy interaction emphasized in Kliem et al. (2016a,b) and Tan (2019). We also find notable empirical evidences concerning the importance of fiscal policy regime in generating their cooperation. The dynamic response of monetary policy to past fiscal policy factor contributes to an appreciable coherence between the two policy regime factors in low-frequencies, while endogenous feedback and contemporaneous policy coordination channels drive up coherence in high-frequencies.

We estimate latent monetary and fiscal policy factors and interpret them as policy makers' internal information. To help interpretation of monetary and fiscal policy factors, we link each of the estimated policy factors to a large pool of macro and financial variables using the adaptive least absolute shrinkage and selection operator (LASSO). We report all selected predictors for both policy factors, and note that some variables, such as net interest payment to government spending ratio, are selected for both monetary and fiscal policy factors. We believe this result offers clear, albeit indirect, evidence of policy interaction.[6]

Lastly, we conduct an impulse response analysis to evaluate the propagation process of policy shocks in future regime determination. Under a set of recursive identifying assumptions, we decompose monetary and fiscal policy disturbances and regime factor innovations into four orthogonal components labeled as monetary and fiscal policy shocks and policy factor shocks. The responses of the two policy factors to monetary and fiscal policy shocks show clear positive comovements, which supports a coordination between the two policies. We identify three major channels in generating policy interaction. The main channel in the short-term shock propagation is the feedback from both policy shocks to the fiscal policy factor. Another important short-term channel is the contemporaneous correlation between the policy factor innovations induced by the fiscal policy factor shock. In the longer term, the primary channel of the shock propagation is the monetary policy factor's responses to the past fiscal policy factors. When this channel is suppressed, we observe a significantly weaker long-term interaction between the policy factors.

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 our empirical specification and provides the plausibility of estimates. We measure coherence between policy regime factors using a frequency domain analysis and link our estimated policy regime factors to key macroeconomic and financial variables by the adaptive LASSO. In Section 4, we add an impulse response analysis to elicit the propagation mechanism of

[6]The fact that the ratio of net interest to spending predicts both policy factors implies that our regime-switching model with endogenous feedback may implicitly account for the effect of this endogenous variable on predicting a regime change. From the U.S. historical accounts, we find that when this ratio is high, Congress tends to do fiscal consolidation, which we may view as a regime change.

policy shocks to changes in policy regimes under a recursive identification assumption. Section 5 concludes the paper, and the Appendices provide results from robustness checks and a description for the adaptive LASSO method.

2 Policy Rules with Bivariate Policy Regime Factor

In the existing literature, regime-switching policy rules abound. Among many that focused on monetary and fiscal policy interactions, Davig and Leeper (2006b) and Favero and Monacelli (2005) estimate Markov-switching monetary and fiscal policy rules separately. Gonzalez-Astudillo (2018) extends this approach and analyzes policy interactions in a bivariate system of policy rules. Bianchi and Melosi (2017) consider a Markov-switching VAR to capture stylized facts after World War II in the U.S. and find that during the zero lower bound period, fiscal shocks play a leading role in explaining the inflation dynamics. In a Markov-switching DSGE model, Bianchi (2012) investigates the U.S. monetary and fiscal policy mix. Bianchi and Ilut (2017) estimate a model for the U.S. economy with changes in monetary and fiscal policy mix and explain why inflation dropped in the 1980s in terms of the policy change.

All works above are, however, based on the exogenous regime-switching models, in which the switching of policy behaviors is entirely exogenous. A major difference between our regime-switching policy rules and the conventional ones is the presence of endogenous self-feedback and cross-feedback. We model the endogenous feedback channels in such a way that we may readily see how policy regimes are affected by policy disturbances reflecting the state of the economy.[7] Moreover, to describe and measure dynamic interactions of monetary and fiscal policies, we introduce a bivariate autoregressive latent policy factor that determines policy regimes. Our specification of regime-switching policy rules, therefore, allow us to investigate presence of coordination between monetary and fiscal authorities by measuring interactions between the two policy regime factors.

2.1 Endogenous Feedback in Regime-Switching Policy Rule

To describe the essence of our regime-switching model, we first consider the following generic policy rule with time-varying policy coefficients that evolve according to the endogenous regime-switching model introduced by Chang et al. (2017)

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

[7] Davig and Leeper (2006a) consider a type of regime-switching monetary policy rule where the coefficients on inflation and output gap are functions of the inflation threshold and lagged inflation. Barthélemy and Marx (2017) also consider a similar regime-switching model in which the monetary policy choice is determined by the level of past inflation. Their models, however, are not directly comparable to ours. Our model assumes that policy regimes are determined by latent policy factors representing unobserved economic fundamentals relevant for regime changes. Our latent factors may also be augmented by predetermined variables such as lagged inflation.

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 exogenous shocks driving other endogenous variables relevant for policy making but not explicitly considered in the given policy rule. Both the target variables x_t and the non-target variables η_t 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.

The time-varying policy behavior of the policy rule is characterized by the state-dependent coefficients β_{s_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 as an indicator function with a continuous latent policy factor w_t and a threshold ψ. Policy regime prevailing at time t therefore corresponds to the realized value of s_t. For example, $s_t = 0$ or $s_t = 1$ signifies dovish or hawkish monetary policy regime under our identification condition $\beta_{s_t=0} \leq \beta_{s_t=1}$. 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 authority's internal information used for policy making purposes. The innovation v_t drives the policy factor w_t which in turn determines the policy regime index s_t. The autoregressive coefficient α measures persistence of policy regime and the level of w_t relative to the threshold ψ indicates strength of the prevailing policy regime.

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

$$\text{corr}(u_t, v_{t+1}) = \rho.$$

The sign and magnitude of the correlation coefficient 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 relevant to policy making but not captured in the target variables x_t is provided to policy regime determination next period. This is in sharp contrast to the time-varying policy rules considered in conventional Markov-switching models where policy regime 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 variables that may affect policy regime 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 surprises 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 vector of parameters. 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} and influence the policy regime next period. Precisely in this sense, we say that policy regime determination in our model is endogenous.

2.2 Policy Rules with Regime-Switching

In the benchmark model, 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.[8] We specify a fiscal policy rule that links tax revenues net of transfer payments τ_t to government purchases g_t, real market value of outstanding government 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. The control variables $\eta_{\pi,t}$ and $\eta_{y,t}$ are obtained as standardized fitted residuals from regressing the potentially endogenous variables 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.[9] 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 regimes signified by the binary regime indexes s_t^m and s_t^f.

In the monetary policy rule (2), $s_t^m = 0$ or $s_t^m = 1$ signifies the policy regime where monetary policy responds to inflation weakly or aggressively, respectively, under the identification condition $\alpha_{\pi,0} \leq \alpha_{\pi,1}$. These two distinct monetary policy regimes refer to the dovish ($s_t^m = 0$) and hawkish

[8] Studies of estimated fiscal rules include 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).

[9] To address the potential endogeneity problem in our policy rule equations, we implement the two-step maximum likelihood procedure suggested in Kim (2009). Handling the endogeneity issue using instrumental variables may not be innocuous according to the critique by Sims and Zha (2006) on the validity of the instruments used in a univariate monetary policy rule equation.

($s_t^m = 1$) monetary regimes defined earlier. Analogously, in the fiscal policy rule (3) with the identification condition $\beta_{b,0} \leq \beta_{b,1}$, $s_t^f = 0$ or $s_t^f = 1$ represents the policy regime where fiscal authority responds to debt weakly or strongly, paying less or more attention to debt stabilization. Similarly, these two distinct fiscal policy regimes are associated with the dovish ($s_t^f = 0$) and hawkish ($s_t^f = 1$) fiscal regimes defined earlier. For our subsequent discussions on prevalent policy regimes, we consider four possible monetary and fiscal policy combinations depending on responses of interest rate to inflation and of tax revenue to real debt: (1) hawkish-monetary/hawkish-fiscal (doubly-hawkish) mix with strong response of monetary authority to inflation and strong response of fiscal authority to debt, (2) dovish-monetary/dovish-fiscal (doubly-dovish) mix with weak response of central bank to inflation and weak response of fiscal authority to debt, and similarly the other two combinations are defined with (3) hawkish-monetary/dovish-fiscal, and (4) dovish-monetary/hawkish-fiscal. In the doubly-hawkish and doubly-dovish mixes, the policy factors move in the same direction, which is conducive to policy coordination. In contrast, the policy factors move in the opposite directions in the other two policy combinations defined with hawkish-monetary/dovish-fiscal and dovish-monetary/hawkish-fiscal mixes, making policy coordination less likely.

In our specification, monetary and fiscal policy disturbances are considered as the residual parts of the policy instrument that are not predicted by the policy target variables. The policy disturbances 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 Federal Reserve (Fed) reacts to short-run economic states while operating under the dual mandate.[10] A fiscal policy disturbance $u_{f,t}$ may contain similar economic concerns as those faced by the Fed, but it may include additional concerns to the fiscal policy maker including a multitude of political considerations.

2.3 Policy Regime Factors with Endogenous Feedback

We specify the regime index s_t^i, $i \in \{m, f\}$ in each of the 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. We consider dynamics of the two policy regime factors jointly by assuming them as a bivariate vector $w_t = (w_{m,t}, w_{f,t})'$ which evolves as a stationary vector autoregressive process

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

[10]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 years remarkably well....There is a significant deviation (of the federal funds rate (FFR) to policy rule) in 1987 when the Fed responds to the crash in the stock market by easing interest rates." This statement supports our interpretation of $u_{m,t}$.

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 $w_{f,t}$. As will be discussed in detail below, we allow dynamic feedback from current policy disturbances $u_t = (u_{m,t}, u_{f,t})'$ to next period policy factor innovation $v_{t+1} = (v_{m,t+1}, v_{f,t+1})'$, and refer to it as *endogenous feedback* reflecting the endogenous nature of the policy disturbances. We 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 AR coefficient matrix A in (5) and the correlation matrix P in (6) together describe dynamics of policy regime factors which determine monetary and fiscal policy regimes and their interactions. 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 AR coefficient matrix A indicating interactions between current and lagged policy factors. We refer to it as the *dynamic interaction channel* because A directly captures the effects of the past policy factors on the current policy factors. Specifically, a_{mm} (a_{ff}) shows persistence of monetary (fiscal) policy regime, and a_{mf} (a_{fm}) signifies the effect of past fiscal (monetary) policy regime on current monetary (fiscal) policy regime.

The estimated correlation matrix P allows us to infer the mechanism underlying the feedback from current policy disturbances to policy regime determination in the next period. We say that there exists endogenous feedback in the switching of policy regimes if $P_{vu} \neq 0$, and that the switching is exogenous if otherwise. We will refer to the policy interaction channel characterized by P as *endogenous feedback channel.* Our bivariate system of policy rules features two types of dynamic feedback channels, namely, self-feedback and cross-feedback. First, *self-feedback* is defined for each policy rule as correlation between the current policy disturbance and its own policy factor innovation in next period. The self-feedback therefore occurs within each policy rule, channeling information from its own past policy disturbance to its current policy factor. The monetary self-feedback is measured by ρ_{v_m,u_m} and it represents the impact from current monetary policy disturbance $u_{m,t}$ to next period monetary policy factor innovation $v_{m,t+1}$, and therefore to monetary policy factor $w_{m,t+1}$ next period. For example, consider a situation where the monetary policy sets the interest rate above the level implied by target variables. In this case, we have a positive monetary policy disturbance, and, if the self-feedback is positive, this predicts an increase in the future monetary policy regime factor, which in turn makes the hawkish monetary regime more likely in the next period.

Second, *cross-feedback* captures correlation between the current policy disturbance in one policy rule and the next period innovation of policy factor in the other policy rule. The cross-feedback is a novel feature introduced with our bivariate system of policy factors and policy rules. It occurs across policy rules, either from past monetary policy disturbance to current fiscal policy factor, or from past fiscal policy disturbance to current monetary policy factor. Specifically, cross-feedback from monetary policy to fiscal policy measured by ρ_{v_f,u_m}, for example, quantifies how much and in what direction the current monetary policy disturbance $u_{m,t}$ influences next period fiscal policy factor innovation $v_{f,t+1}$. The cross-feedback thus allows us to analyze whether and how a change in monetary regime may lead to a switching in the fiscal regime. This is particularly relevant since many believe that central banks take into account the regime of fiscal policy in making its policy choices. A policy disturbance entails both feedback effects. For example, if the monetary policy disturbance $u_{m,t}$ materializes at t, it will affect the monetary policy regime change next period reflected in $\alpha_\pi(s^m_{t+1})$ through self-feedback channel, and the switching in fiscal policy regime reflected in $\beta_b(s^f_{t+1})$ through cross-feedback channel.

Self-feedback and cross-feedback influence the evolution of monetary and fiscal policy mixes, as P is involved in the calculation of time-varying transition probability from one policy mix to another. To describe the idea, we consider the time-varying transition probabilities obtained for the multi-factor endogenous regime-switching model in Chang et al. (2020). First, we purge out the effect of realized policy disturbances u_{t-1} from the policy factor innovations v_t to obtain the orthogonal policy factor shock process

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

Then we use it to compute, for example, the transition probability of staying in the doubly-dovish mix

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

where $\Phi_{v|u}$ is the distribution function of the policy factor shock 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 control variables for endogeneity correction. We zoom into the term $P_{vu}P_{uu}^{-1}u_{t-1}$ in the above transition probability, and let $P_{uu} = I$ to highlight the role of self-feedback and cross-feedback in the time-varying transition probabilities.[11] We may decompose each component of $P_{vu}P_{uu}^{-1}u_{t-1}$ into self-feedback and cross-feedback terms as follows

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

If $P_{vu} > 0$ element-wise, then a positive disturbance to either policy rule, $u_{m,t-1} > 0$ or $u_{f,t-1} > 0$, increases both monetary and fiscal policy factors, which in turn reduces the probability of staying in the doubly-dovish mix in the next period through both self-feedback and cross-feedback channels.

Policy interactions in our model are also driven by the contemporaneous policy interaction arising from correlation between the two policy factor innovations. As discussed earlier, policy factor innovations receive feedback from past policy disturbances. It is therefore meaningful to devise a measure of contemporaneous policy interaction net of feedback effects. To this end, we purge out feedback effects from the policy factor innovations and measure the policy interaction taking place only in the current period by the correlation between residual parts of the policy factor innovations. We call this net measure of policy interaction the *contemporaneous policy coordination*, and quantify it using the correlation between current policy factor innovations v_t net of dynamic influence from u_{t-1} through the endogenous feedback channels discussed above. Specifically, we 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 interaction channel allows us to investigate the existence and magnitude of contemporaneous coordination of policy authorities in determining their policy regimes.

3 Data and Estimation Results

We use quarterly U.S. data from 1961:Q1 to 2014:Q2 for our empirical exercises. 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 potential real GDP measured by Congressional Budget Office. 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.[12] 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,[13] and g_t the real per capita federal government

[11] The term $P_{vu}P_{uu}^{-1}u_{t-1}$ is the conditional mean vector of v_t given u_{t-1}.

[12] 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 Federal Economic Research Data (FRED).

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

consumption plus investment expenditures. Monetary policy variables are obtained from the FRED database, and fiscal policy variables are from the National Income and Product Accounts (NIPA) Table 3.2 (τ_t, g_t), and Federal Reserve Bank of Dallas - U.S. Economic Data and Analysis (b_t). To obtain the control variables to handle potential endogeneity in policy target variables, 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 ML method using the modified Markov-switching filter developed by Chang et al. (2020). The estimates include coefficients of monetary and fiscal policy rules and parameters for policy regime factor dynamics, including thresholds, the AR coefficient and correlation matrices specified in the previous section. In the following subsections, we report estimates of the model, discuss plausibility of estimates, and provide interpretation of policy regime factors. Based on our estimates, we also obtain evidence on monetary and fiscal policy interactions from frequency domain and shrinkage regression analyses.

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	[0.664,0.909]	$\beta_{\rho,0}$	0.117	[0.002,0.242]	ψ_m	0.611	[-1.393,2.605]
$\alpha_{\rho,1}$	0.755	[0.599,0.935]	$\beta_{\rho,1}$	0.946	[0.869,0.955]	ψ_f	-2.472	[-3.566,-1.722]
$\alpha_{c,0}$	1.746	[0.038,3.504]	$\beta_{c,0}$	3.313	[3.010,3.567]	a_{mm}	0.152	[-0.582,0.533]
$\alpha_{c,1}$	1.430	[-0.451,2.835]	$\beta_{c,1}$	1.865	[1.183,2.720]	a_{fm}	0.053	[-0.040,0.178]
$\alpha_{\pi,0}$	0.603	[0.087,0.659]	$\beta_{b,0}$	0.083	[0.083,0.083]	a_{mf}	1.128	[0.258,1.715]
$\alpha_{\pi,1}$	1.758	[1.082,2.542]	$\beta_{b,1}$	0.124	[0.084,0.163]	a_{ff}	0.719	[0.579,0.800]
$\alpha_{y,0}$	0.412	[0.084,0.710]	$\beta_{y,0}$	0.342	[0.288,0.411]	$\rho_{u_m u_f}$	0.155	[0.030,0.343]
$\alpha_{y,1}$	-0.004	[-0.404,0.840]	$\beta_{y,1}$	0.285	[0.136,0.425]	$\rho_{v_m u_m}$	0.863	[0.190,0.952]
α_η^π	0.124	[-0.008,0.203]	$\beta_{g,0}$	-0.312	[-0.335,-0.307]	$\rho_{v_f u_m}$	0.718	[0.341,0.922]
α_η^y	0.041	[-0.053,0.147]	$\beta_{g,1}$	-0.031	[-0.206,0.125]	$\rho_{v_m u_f}$	0.409	[-0.086,0.707]
σ_m	0.467	[0.281,0.559]	β_η^y	0.026	[-0.005,0.042]	$\rho_{v_f u_f}$	0.175	[0.048,0.613]
			σ_f	0.137	[0.117,0.152]	$\rho_{v_m v_f}$	0.930	[0.588,0.989]
						$\rho_{vv \cdot u}$	0.293	[0.058,0.653]

3.1 Estimates of Regime-Switching Policy Rules

Table 1 reports the ML estimates and 90% confidence intervals obtained using the stationary block bootstrap procedure by Politis and Romano (1994).[14] We may infer from the estimates of the state-dependent parameter on inflation α_π in the first column of Table 1 that monetary policy switches between dovish regime where the central bank responds weakly to inflation ($\alpha_{\pi,0}$=0.60), and hawkish regime where it responds strongly to inflation ($\alpha_{\pi,1}$=1.76). In a dovish monetary regime, more attention is given to output gap in comparison to the hawkish monetary regime where the monetary authority puts more weight on inflation control and responds insignificantly to

[14] We obtain percentile bootstrap confidence intervals (Efron and Tibshirani, 1993) by estimating 1000 block bootstrapped samples of length 200. The average block size is 17 for the stationary block bootstrap, which is selected by averaging the optimal block size for each vector of time series via the approach by Politis and White (2004).

output gap. In both hawkish and dovish regimes, estimates of monetary policy rule clearly show smooth adjustment of the policy interest rate with respect to the target interest rate.[15]

The middle column of Table 1 shows that fiscal policy switches between dovish and hawkish regimes in which fiscal authority reacts to debt relatively weakly and strongly ($\beta_{b,0}$=0.08 and $\beta_{b,1}$=0.12). According to our estimates, in both fiscal policy regimes, taxes are raised systematically and strongly with the rise in output gap, as one would expect from built-in stabilizers in the tax system. In the dovish fiscal regime, estimates of the fiscal policy rule show that tax revenues and government spending move in the opposite directions. These estimates describe the fiscal policy behaviors during the recession after the global financial crisis: several tax cuts and increased government spending as part of government stimulus packages. At the same time, fiscal authority responds to debt weakly, reaching an unusual level of debt. Those estimates describe that under the dovish fiscal regime, fiscal authority focuses on real activity and puts less attention to debt stabilization. The hawkish fiscal regime, on the other hand, is characterized by a stronger response to debt with more attention on debt stabilization. The estimated smoothing coefficients of the fiscal policy rule imply different smoothing behaviors depending on the prevailing fiscal policy regime. When the fiscal policy pays less attention to debt, a strong adjustment with respect to the target occurs every quarter. However, when fiscal policy clearly acts as a debt stabilizer, only about 5% of the adjustment occurs with respect to the target.

3.2 Estimates of Policy Factor Dynamics

The last column of Table 1 shows the estimated monetary and fiscal 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 determination of policy regimes. Three notable findings follow. First, we observe that the fiscal policy factor significantly impacts the monetary policy factor dynamically in such a way that the monetary authority responds to inflation more (less) aggressively when the fiscal authority pays 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 strongly to lagged fiscal policy factor $w_{f,t-1}$ (a_{mf}=1.13), while fiscal policy factor $w_{f,t}$ responds weakly to lagged monetary policy factor $w_{m,t-1}$ (a_{fm}=0.05). Therefore, we may say that the next period monetary policy factor can be explained by the current fiscal policy factor, while the next period fiscal policy factor can not be explained by the current monetary policy factor.

Second, we find strong evidence of endogenous feedback. Note that our regime-switching policy rules are equivalent to those of exogenous Markov-switching policy rules if all endogenous feedback channels are shut down (P_{vu}=0). We find that a past monetary policy disturbance $u_{m,t-1}$ yields significant influences on monetary and fiscal policy regimes through both 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 in

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

the monetary policy rule means that a positive monetary policy disturbance $u_{m,t}$ in the current period forecasts a higher monetary policy factor $w_{m,t+1}$, which implies that hawkish monetary policy regime is more likely in the next period. For example, a news shock contained in stock prices portending higher future inflation would raise the nominal interest rate above the level that current inflation predicts. And this positive policy disturbance forecasts a higher monetary policy factor, which means monetary authority is more likely to respond aggressively to inflation in the next period. Strong cross-feedback from past monetary policy disturbance $u_{m,t-1}$ to current fiscal policy factor $w_{f,t}$ indicates that monetary policy disturbance influences fiscal policy behavior. For example, given a positive $u_{m,t-1}$ that raises interest rate and induces a strong response of central bank to future inflation, fiscal authority may adjust taxes to assure fiscal solvency. According to our estimates, fiscal authority tends to put more attention on stabilizing debt when a positive monetary policy disturbance materializes, and these findings together suggest a doubly-hawkish mix.

In contrast to strong endogenous feedback from a monetary policy disturbance, a fiscal policy disturbance generates a weak self-feedback effect to fiscal factor (ρ_{v_f,u_f}=0.17) and a moderate cross-feedback effect to monetary factor (ρ_{v_m,u_f}=0.41).[16] Fiscal policy disturbances are often considered as exogenous one-time events and therefore they may not be reflected in fiscal authority's purposeful behaviors, such as systematic responses to debt level or discretionary economic stimulus. Cross-feedback from fiscal policy disturbance to next period monetary policy regime may reflect the fact that central bank routinely predicts the fiscal policy instrument and targets. For instance, an expansionary fiscal policy disturbance, regardless of its nature, exogenous or endogenous, directly induces nominal and real impacts on the economy, and the monetary policy authority may systematically adjust its policy rule based on the fiscal policy disturbance. In sum, we observe that a monetary policy authority strongly adjusts its policy regime via both self-feedback and cross-feedback, while a fiscal policy authority updates its policy regime primarily through cross-feedback.

Lastly, we observe significant contemporaneous coordination between the two policy authorities. Strong correlation between policy factor innovations (ρ_{v_m,v_f}=0.93) represents strong positive comovement between monetary and fiscal policy factors, which gives strong evidence for coordination between policy authorities.[17] By purging out the effects from past policy disturbances u_{t-1}, we obtain significant contemporaneous correlation between the residual policy factor innovations ($\rho_{vv\cdot u}$=0.29)

3.3 Coherence of Policy Regime Factors

Using the ML estimates of policy factor dynamics, we measure the policy coordination and importance of the three interaction channels introduced earlier by computing coherence between policy

[16] The latter is statistically insignificant at 90% confidence level.

[17] Gonzalez-Astudillo (2013, 2018) also find a high correlation between the monetary and fiscal policy states, which drives the changes in monetary and fiscal policy coefficients in time-varying coefficient and conventional Markov-switching policy rule specifications.

factors in the frequency domain. To this end, we first write out the (2×2) spectral density matrix of the bivariate policy factor w_t including monetary and fiscal policy factors, $w_{m,t}$ and $w_{f,t}$, as

$$F_w(\lambda) = A^{-1}(e^{i\lambda})F_v(\lambda)A^{-1}(e^{i\lambda})^*, \quad \lambda \in [-\pi, \pi] \tag{7}$$

where F_v is the (2×2) spectral density matrix of policy factor innovations v_t, and $*$ denotes the adjoint operator. Due to the iid assumption on v_t, we have $F_v(\lambda) = P_{vv}$ for all $\lambda \in [-\pi, \pi]$, and this implies the spectral density matrix $F_w(\lambda)$ of the policy factors w_t can be written as

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

where a_{ij} is the ij-th element of the (2×2) AR coefficient matrix A. The coherence between the two policy factors is then measured by

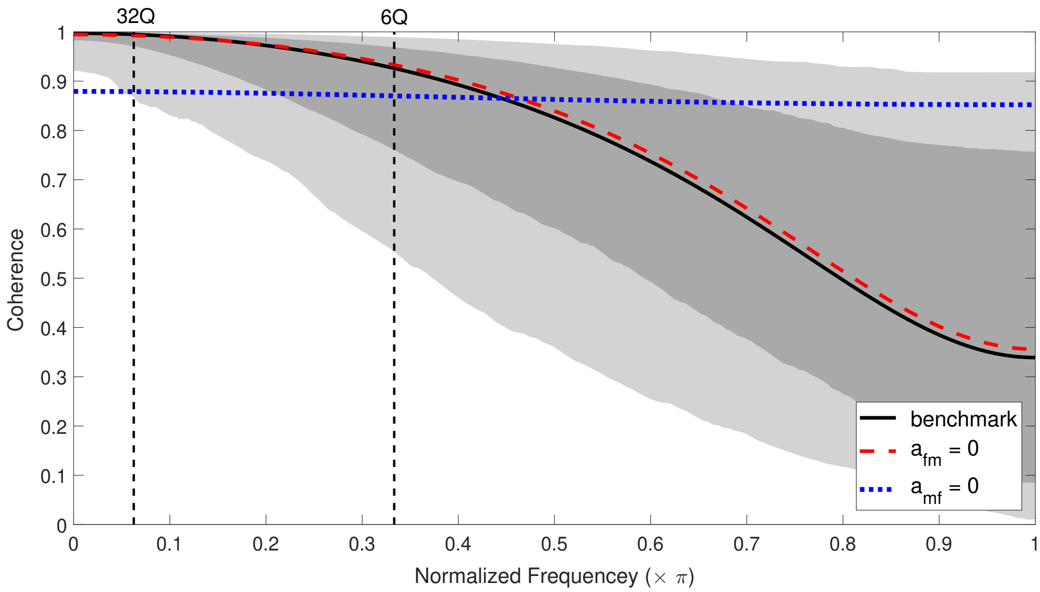
$$\rho^2_{mf}(\lambda) = \frac{|F_{mf}(\lambda)|^2}{F_{mm}(\lambda)F_{ff}(\lambda)}$$

with $F_{mf}(\lambda)$ denoting the cross-spectral density between the monetary and fiscal policy factors, $w_{m,t}$ and $w_{f,t}$. The coherence provides additional information about the strengths of dynamic interaction, endogenous feedback, and contemporaneous coordination channels of monetary and fiscal policy interactions across different frequencies, including the commonly studied short-run, business-cycle and long-run frequencies.

Figure 1 presents the magnitude-squared coherence between monetary and fiscal policy factors across different frequencies λ, analogous to the R^2-statistic capturing the strength of comovement between the two policy factors. The solid black line reports the benchmark coherence. Our benchmark estimates show the existence of coordination between monetary and fiscal authorities across all frequencies. Especially, at lower than and around business cycle frequencies, we observe strong coherence. Our results are consistent with previous literature. 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 using a spectral analysis. Tan (2019) considers a frequency domain analysis for policy interaction in a DSGE model and finds that the low-frequency interaction is important to disentangle the ranking of preferred policy mix between two determinate policy mixes in the U.S. data. In particular, the policy mix in which both monetary and fiscal authorities responds weakly to their policy targets is more important at low frequencies.

Strong coherence between policy regime factors at low-frequencies is potentially connected to

Figure 1: Coherence of Monetary and Fiscal Policy Factors: Dynamic Interaction



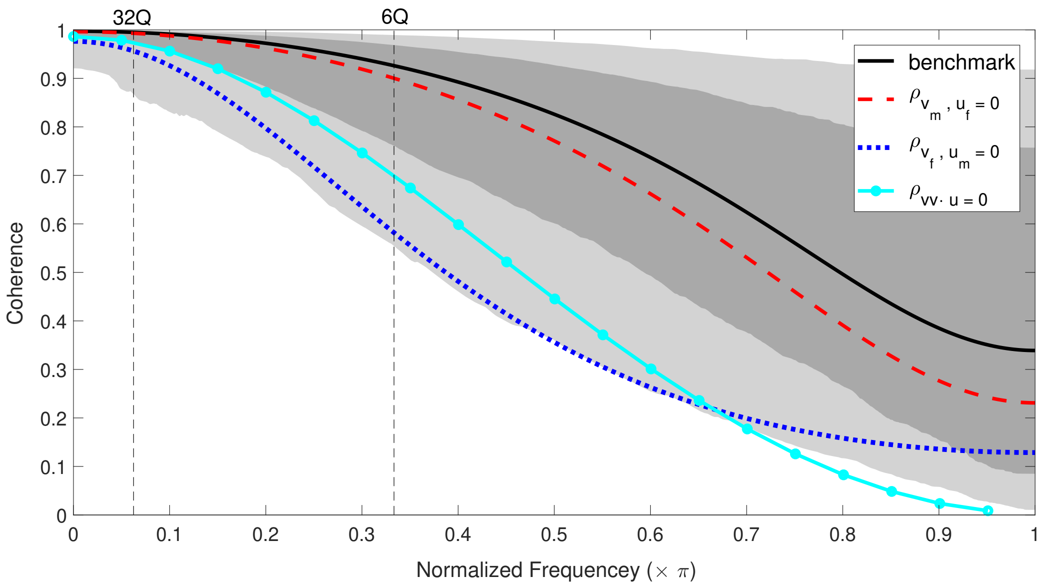
Notes: The graph presents magnitude-squared coherences of monetary and fiscal policy factors with and without dynamic interaction channel. The solid black line is for benchmark case. The dashed red and dotted blue lines are for counterfactual analyses by shutting down dynamic interaction partially, a_{fm}=0 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.

characteristics specific to the fiscal policy. Blanchard and Perotti (2002) identify fiscal policy shocks and discuss 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.[18] On the other hand, low-frequency, say decade-to-decade properties of fiscal variables may capture more systematic reactions to the state of the economy, including debt stabilization and discretionary stimulus. Bianchi and Melosi (2014) demonstrate that current fiscal shocks do not impact the economy under a conventional policy mix in which a central bank stabilizes inflation and a fiscal authority adjusts taxes or government spending to assure fiscal solvency. However, when the economy is under accumulated debt and uncertainty of debt financialization, private agents' belief on the economy's return to the conventional policy mix becomes pessimistic, and past fiscal shock finally impacts inflation dynamics, and therefore induces a change in monetary and fiscal policy regimes.

We conduct two sets of counterfactual analyses to investigate the impacts of our new policy interaction channels, dynamic interaction, cross-feedback, and contemporaneous policy coordination, across different frequencies. Note that only A and P_{vv} are relevant to the calculation of coherence by equation (7). Therefore, in the first counterfactual exercise, we impose zero restrictions on the AR coefficient matrix A, and in the second exercise, we suppress channels in P_{vv} of the correlation

[18] For example, a large one-time payment of National Service Life Insurance benefits to war veterans that caused an increase in net taxes in 1950:Q2, and an increased military spending related to the Korean War buildup in 1951:Q1.

Figure 2: 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 solid black line is for benchmark case. The dashed red and dotted blue 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 solid cyan line with a round mark presents 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.

coefficient matrix P. Figure 1 reports the results from the first set of counterfactual analyses. The dotted blue line plots counterfactual coherence between policy factors when dynamic interaction from current fiscal policy factor to next period monetary policy factor is shut down ($a_{mf} = 0$), while the dashed red line shows counterfactual coherence when dynamic interaction from current monetary policy factor to next period fiscal policy factor is shut down ($a_{fm} = 0$) instead. Without dynamic interaction from current fiscal policy factor to next period monetary policy factor, coherence between policy factors across frequencies flattens. However, in the absence of dynamic interaction from current monetary policy factor to next period fiscal policy factor, changes in coherence are negligible, with only a marginally increased coherence in high frequencies.

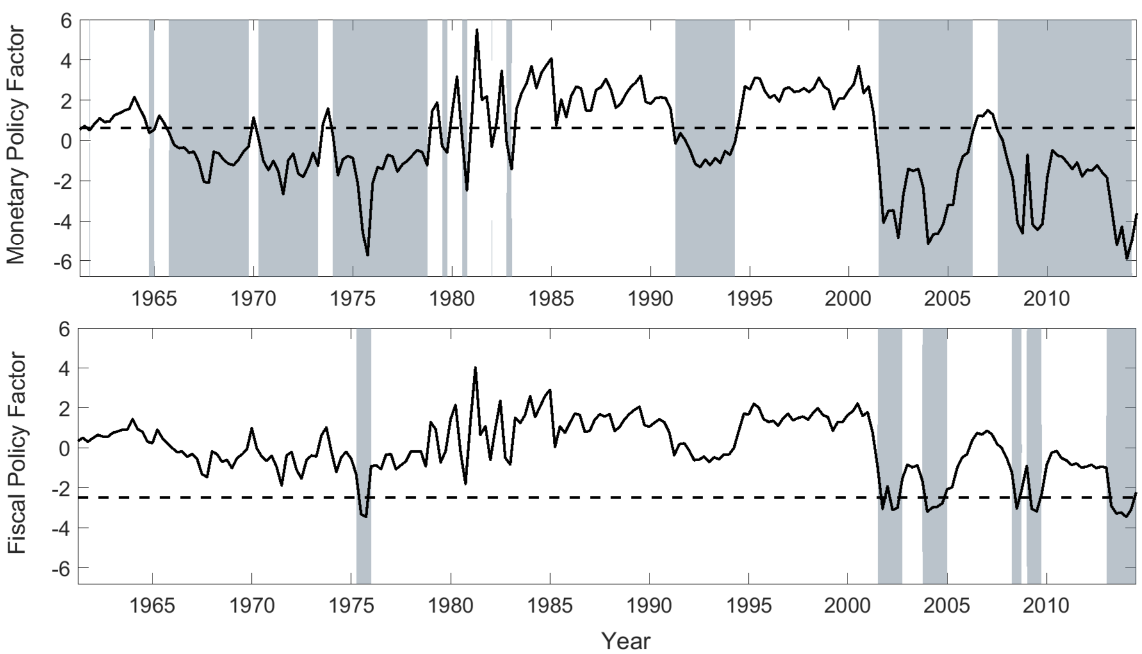
Figure 2 reports the results from the second set of counterfactual analyses in which it shows the impacts of cross-feedback and contemporaneous policy coordination on coherence between monetary and fiscal policy factors. By suppressing contemporaneous coordination ($\rho_{vv\cdot u} = 0$)[19], the strength of the interaction between policy factors decreases across all frequencies but relatively much more in high frequencies as shown by the cyan line with a round mark. We also observe from the dashed red line, obtained assuming $\rho_{v_m,u_f} = 0$,[20] that cross-feedback from past fiscal policy disturbance to

[19]We let $P^{(2,1)}_{vv\cdot u} = 0$ with all else fixed at ML estimates (denote it by $P^o_{vv\cdot u}$), and compute $P^o_{vv} = P^o_{vv\cdot u} + P_{vu}P^{-1}_{uu}P_{uv}$ for the calculation of counterfactual coherence.

[20]We consider P_{vu} with zero restriction on relevant off-diagonal element, either ρ_{v_m,u_f} or ρ_{v_f,u_m}, with all else fixed

current monetary policy factor increases the coherence between policy factors in higher frequencies. In contrast, the dotted blue line, obtained with $\rho_{v_f,u_m} = 0$ imposed, shows that the presence of cross-feedback from past monetary policy disturbance to current fiscal policy factor significantly increases coherence across all frequencies but relatively more in frequencies higher than the business cycle. Our frequency domain analysis therefore reveals significant coherence between policy regime factors across all frequencies, supporting significant coordination between two policy authorities at all frequencies. In particular, we find that the strong dynamic effect from past fiscal policy factor to current monetary policy factor contributes most to the substantial low-frequency interaction between two policies.

Figure 3: Extracted Monetary and Fiscal Policy Factors and Estimated Policy Regimes



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

3.4 Plausibility of Estimates

Figure 3 presents estimated policy mixes that are jointly determined by estimated monetary and fiscal policy factors, $w_{m,t}$ and $w_{f,t}$, and thresholds, ψ_m and ψ_f. Monetary policy is dovish (hawkish) when the extracted monetary policy factor $w_{m,t}$ is below (above) the estimated monetary threshold ψ_m, as shown in the upper panel of Figure 3. Analogously, fiscal policy is dovish (hawkish) when the extracted fiscal policy factor is below (above) estimated fiscal threshold as shown in the lower

at ML estimates (denote it by P^o_{vu}), and compute the counterfactual $P^o_{vv} = P_{vv\cdot u} + P^o_{vu}P^{-1}_{uu}P^o_{uv}$.

panel of Figure 3. Therefore, when upper and lower panels are simultaneously shaded or unshaded, the prevalent policy mix is doubly-dovish or doubly-hawkish.

We examine the plausibility of estimated policy regimes based on historical narratives on monetary and fiscal policies. Our estimated policy regimes seem quite consistent with the narrative accounts of U.S. policy history.[21] The shaded areas in the upper panel of Figure 3 show the dovish monetary policy regime under which central bank responds weakly to inflation. Our results indicate that monetary policy took a dovish regime in most of our earlier sample, except for the period 1961:Q1-1966:Q1, until October 1979 when the Fed changed its operating procedures and responded to inflation aggressively. Since 1979, monetary policy regime has been mostly hawkish except for the two periods, 1993:Q1-1994:Q1 and 2002:Q1-2006:Q2, following the recessions in 1991 and 2001, when the monetary policy was dovish. Davig and Leeper (2006b) note that there were prevailing concerns about low real interest rates and weak responses to inflation in the early 1990s and 2000s. Indeed, during policy deliberations at the Federal Open Market Committee (FOMC) meeting on March 1993, 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)). These concerns might have led the Fed to take the hawkish monetary policy regime when it launched a preemptive strike against inflation in 1994. Also, there were concerns about negative real interest rates since 2001 and the flood of liquidity in 2003 and 2004 (Unsigned (2005a,b)).

Our estimates indicate that monetary policy mostly took a hawkish regime during 2006:Q3-2007:Q4, and this is consistent with historical accounts which show that prior to 2006:Q3 the interest rate had increased and was kept high until 2007:Q3. At the 2006 August meeting, Governor Lacker expressed his 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. With moderately elevated inflation, the FOMC had kept a relatively high FFR target during this period based on the concerns related to potential inflation pressure.[22] After the recent global financial crisis, the prevalent monetary policy regime had been dovish with the target for the FFR set at between 0 and 1/4 percent by the end of our sample period.

For the fiscal policy regimes, the shaded areas in the lower panel of Figure 3 indicate a dovish fiscal policy regime in which fiscal authority puts less attention to debt stabilization. Overall, the estimated fiscal policy regimes accord well with narrative accounts of important historical episodes. During our sample period, the prevailing fiscal policy regime was hawkish except for some temporary changes to a dovish regime. The periods of dovish fiscal regime are related to discretionary tax policy targeting real activities during economic recessions. For example, the 1975 fiscal expansion

[21] We draw narrative evidence from Pechman (1987), Poterba (1994), Stein (1996), Steuerle (2002), Romer and Romer (2004), and Yang (2007).

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

initiated by President Ford's tax cut following the oil price shock was detected as a period with a weak response of tax revenue to debt. During the periods where monetary policy mostly remained in the hawkish regime, we also find that fiscal authority took a hawkish regime to focus on debt stabilization. Also we observe that President George W. Bush took a dovish fiscal regime and paid less attention to debt stabilization through subsequent tax reductions in 2002 and 2003.

In 2008, the Congress passed the Economic Stimulus Act to boost the economy from the recession after the 2007-2008 global financial crisis, and fiscal policy deviated from its previous hawkish regime by being less sensitive to growing debt. During 2010-2013, we observe a hawkish fiscal policy regime contrary to the popular belief at the time that the fiscal authority was dovish putting more attention to economic stimulus. Our estimated fiscal policy regimes after the financial crisis are indeed consistent with FOMC statements and minutes. In the FOMC meetings from January 2009 to December 2009, several FOMC statements mentioned that joint fiscal and monetary stimulus would contribute to a strengthening of economic growth. However, in the following FOMC meetings during March 2013 to October 2013, there were concerns about the limited impact of fiscal policy, and this led to somewhat more restrictive fiscal policy that resulted in strained and insufficient economic growth.[23] Several subsequent FOMC statements stated that this fiscal policy was restraining economic growth, although the extent of this restraint may have been diminishing.[24]

In sum, we observe that the prevailing policy mix in our early sample period was doubly-hawkish. During the 1970s, the prevalent policy mix switched to a dovish-monetary/hawkish-fiscal, except for a brief period of doubly-dovish mix.[25] During the Volcker period, it is well known that Fed aggressively reacted to inflation, so the dominant policy mix was likely doubly-hawkish. More recently, following the global financial crisis, the prevalent policy mix switched from doubly-hawkish to doubly-dovish. After the global financial crisis, we find that monetary policy regime was mostly dovish while fiscal policy regime was mixed, and therefore we observe two policy combinations: doubly-dovish mix and dovish-monetary/hawkish-fiscal mix. Estimated fiscal policy regimes and FOMC statements after the financial crisis suggest that the fiscal policy authority, along with a dovish Fed, might have not been aggressive enough to provide economic stimulus necessary for the recovery from the Great Recession.

3.5 Understanding Policy Regime Factors

In this subsection, we explore the implications of estimated monetary and fiscal policy factors on policy coordination. We observe that policy regimes may not be cooperating at all times. There are periods in which monetary authority responds weakly to inflation while fiscal authority strongly reacts to debt, but even in these periods the underlying policy regime factors appear

[23]In this period, we observe increases in tax revenue, moderate decrease in government spending and slow-downed increase in the debt level compared to those from previous years.

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

[25]Ettmeier and Kriwoluzky (2020) estimate a DSGE model with policy interactions and show that both policy mixes detected in our empirical study prevailed in the pre-volcker period.

to co-move consistently.[26] Several empirical studies on policy interaction using regime-switching specifications find moderate or weak coordination in policy regimes. Favero and Monacelli (2005) and Bianchi (2012) find that monetary and fiscal policy regimes are not synchronized with several non-cooperating periods, and monetary and fiscal authorities cannot always commit credibly to following one of the two cooperative policy combinations. However, those findings neither imply that one policy authority ignores the other's behavior nor suggest that it remains oblivious to the consequence of lack of cooperation. Monetary and fiscal authorities seem to recognize the existence of strong interdependence between their policies, as quoted in Bianchi and Melosi (2019). From the estimated policy factors, we infer clear comovements between policy authorities' systematic behaviors.

Estimated policy factors allow us to understand policy interaction better by linking the policy factors to macroeconomic and financial variables. We interpret latent policy factors as an internal information set used by each policy authority to determine its policy regime. Estimated policy factors, therefore, can be used in policy analyses as proxies for the internal information of policy authorities. To enhance interpretation of monetary and fiscal policy factors, we link each of the estimated policy factors to a large set of variables that are commonly considered in policy studies. To build a pool of candidate macro-finance variables that may have explanatory power for policy factors, we consider a big data set known as FRED-QD that is 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).[27] We use 216 quarterly time series among the original 248 time series in FRED-QD, excluding the time series that are not available from 1961:Q1. In addition, we add the output gap and six more fiscal variables to better understand whether and how monetary and fiscal policy factors are explained by macro and fiscal variables. The six additional fiscal variables include the ratio of net interest payment to government expenditure, ratio of net interest payment to debt, real per capita debt, real per capita government spending, ratio of military spending to GDP, and real per capita tax revenues. The policy instrument variables, short-term interest rate and real per capita tax revenues, are excluded in our analysis of monetary and fiscal policy factors, respectively.

To select a set of such macro-finance variables explaining each of the estimated policy factors, we consider the 223 variables above and employ the adaptive LASSO (least absolute shrinkage and selection operator) method. A detailed description of our implementation of the adaptive LASSO method is provided in the Appendix.

Table 2 reports the selected variables for the estimated policy factors.[28] The top panel of Table 2 presents twenty-three variables selected for the monetary policy factor and the categories they belong to. Naturally, the variables that are commonly considered in monetary policy analysis are

[26] The correlation between policy factors based on our estimates is 0.98, implying a strong coordination between the two policy authorities.

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

[28] Selected variables are listed in descending order by absolute value of estimated coefficients.

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: 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
Industrial production: durable materials	Industrial production
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

selected with relatively large coefficient estimates. They include price index, term structure of interest rates, industrial production, and employment. Another selected variable, consumer sentiment index, reflects how private agents feel about economic conditions in the short-term and long-term. They may take signals from changes in monetary policy regime to form their expectations on future economic conditions. Also the net interest payment to government spending ratio is selected as one of the important variables that explain the level of monetary policy factor.

Similarly, the bottom panel of Table 2 presents seven variables selected for the fiscal policy factor and the categories they are associated with. Selected variables include a subset of those selected for the monetary policy factor. Net interest payment to government spending ratio is selected with large estimated coefficients, and several variables related to interest rates are also selected for the fiscal policy factor, implying that fiscal policy regime is closely related to the term structure of interest rates. The blue-colored variables are the selected variables shared by both policy factors.

We observe that selected variables for the monetary policy factor cover more categories of economic variables than those selected for the fiscal policy factor. Selected variables for both policy factors include interest rate, production, stock and credit market, consumer sentiment, and net interest payment to outlay ratio.

The most significant finding from our 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 Fed controls inflation strongly by raising interest rate, the fiscal authority may be motivated to act upon a high interest burden to push for fiscal consolidation which aims at reducing government deficits and debt accumulation. Indeed, historical accounts show a tendency that several significant legislation to increase taxes followed to periods of increasing net interest payment to government expenditure ratio. Our findings therefore help us to infer what policy makers consider in their decision-making, and they present a clear, albeit indirect, evidence of policy interaction.[29]

4 Policy Interactions

We aim to elicit the purposeful nature of policy making to better understand the interaction between monetary and fiscal policies. With our new regime-switching model, we analyze three channels through which policy makers may interact with each other, namely endogenous feedback, dynamic interactions, and contemporaneous coordination. Identification assumptions precede the measurement of the effects of these channels. In general, a general equilibrium model is required to fix a justifiable set of identifying assumptions. Nevertheless, in an effort to trace out the effects of the three aforementioned policy interaction channels in our reduced-form bivariate system, we adopt a rather strong identification assumption of slow-moving fiscal shocks from the literature, and report a number of interesting suggestive findings.

4.1 Decomposing Policy Disturbances and Policy Factor Innovations

For the impulse response analysis, we first identify four orthogonal shock components from the current policy disturbances, $u_{m,t}$ and $u_{f,t}$, and the next period policy factor innovations, $v_{m,t+1}$ and $v_{f,t+1}$. Our identification scheme is motivated by the assumptions used in previous literature and is consistent with our endogenous feedback and contemporaneous policy coordination channels defined in the previous sections.

We adopt the exogeneity assumption of fiscal policy in the existing literature, and specify the contemporaneous relationship between the monetary and fiscal policy disturbances, $u_{m,t}$ and $u_{f,t}$. Several studies on the fiscal policy rule demonstrate that fiscal policy is more exogenous than monetary policy, with the fiscal policy showing more low-frequency movements. See, among

[29] We may add our extracted policy factors into various econometric models, such as VAR and factor-augmented VAR, as proxies of changes in monetary and fiscal policy regimes, to investigate how the policy factors are related to and affected by the state of the economy.

others, Fatás and Mihov (2001), von Jagen et al. (2001), Blanchard and Perotti (2002), Favero and Monacelli (2005), and Mountford and Uhlig (2009) for example. In particular, Melitz (1997) emphasizes the exogeneity of fiscal policy shock after removing the systematic reactions anticipated by debt and output, which is consistent with our fiscal policy rule specification. Assuming a slow-moving fiscal policy and exogeneity of its disturbance, Muscatelli et al. (2002) analyze the relationship between monetary and fiscal policies by putting a fiscal policy variable ahead of interest rate in their VAR model. A similar idea is used in Kliem et al. (2016a,b) to justify their time-varying coefficient VAR specification.

Note that the next period policy factor innovations, $v_{m,t+1}$ and $v_{f,t+1}$, are affected by the current policy disturbances, $u_{m,t}$ and $u_{f,t}$, through endogenous feedback channels, but not vice versa by construction. We may therefore assume that $v_{m,t+1}$ and $v_{f,t+1}$ are more endogenous than $u_{m,t}$ and $u_{f,t}$, and use the same slow-moving characteristic of fiscal policy to specify contemporaneous correlation between monetary and fiscal policy factor innovations, $v_{m,t+1}$ and $v_{m,t+1}$. Under these assumptions, we obtain the following system of equations of the two policy disturbances and the two policy factor innovations:

$$\begin{aligned} u_{f,t} &= e_{f,t} && (8) \\ u_{m,t} &= \lambda e_{f,t} + \sqrt{1-\lambda^2}\, e_{m,t} && (9) \\ v_{f,t+1} &= \phi_{11} e_{f,t} + \phi_{12} e_{m,t} + \sqrt{1-\phi_{11}^2-\phi_{12}^2}\, \varepsilon_{f,t+1} && (10) \\ v_{m,t+1} &= \phi_{21} e_{f,t} + \phi_{22} e_{m,t} + \phi_{23}\varepsilon_{f,t+1} + \sqrt{1-\phi_{21}^2-\phi_{22}^2-\phi_{23}^2}\, \varepsilon_{m,t+1}. && (11) \end{aligned}$$

The four orthogonal shocks on the right hand side, i.e., $e_{f,t}$, $e_{m,t}$, $\varepsilon_{f,t+1}$ and $\varepsilon_{m,t+1}$, are assumed to be standard normal and independent of each other at all leads and lags. The six coefficients, λ, ϕ_{11}, ϕ_{12}, ϕ_{21}, ϕ_{22} and ϕ_{23}, fall in $[-1, 1]$, 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.

For convenience, we label $e_{m,t}$ and $e_{f,t}$, respectively, as monetary and fiscal policy shocks in what follows. The future fiscal policy factor innovation $v_{f,t+1}$ is a linear combination of the current monetary and fiscal policy shocks, $e_{m,t}$ and $e_{f,t}$, and an additional shock $\varepsilon_{f,t+1}$. The shock $\varepsilon_{f,t+1}$ 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 $u_{m,t}$ by construction. We label $\varepsilon_{f,t+1}$ as the fiscal policy factor shock. Finally, we specify the future monetary policy factor innovation $v_{m,t+1}$ as a linear combination of $e_{m,t}$, $e_{f,t}$, $\varepsilon_{f,t+1}$ and an additional shock $\varepsilon_{m,t+1}$ that affects only the future monetary factor innovation $v_{m,t+1}$. We subsequently call $\varepsilon_{m,t+1}$ the monetary policy factor shock.

The assumptions we adopt to identify the four orthogonal shocks in our system of equations specified in (8) lead to a recursively identified structural VAR model. Indeed, the four equations in (8) form a just-identified triangular system. To see this clearly, we write the system (8) in matrix form as

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

which we may rewrite more compactly as

$$\mathbf{u}_t = \Phi \mathbf{e}_t \tag{12}$$

where the four orthogonal components introduced in (8) are combined as a shock vector

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

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 contemporaneous correlations among the reduced-from innovations in $\mathbf{u}_t$. Due to the triangular structure, Φ is just-identified and can be easily obtained from the Cholesky 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 $P = LL'$.

The triangular structure of our orthogonal shocks in (12) allows us to relate the endogenous feedback channels of monetary-fiscal policy interactions, defined originally based on correlations among reduced-form innovations in $\mathbf{u}_t$, with more interpretable structural shocks in $\mathbf{e}_t$ using the contemporaneous correlation matrix Φ. To illustrate this point, recall that the monetary policy self-feedback is defined as the feedback from the current monetary policy disturbance $u_{m,t}$ to next period monetary policy factor innovation $v_{m,t+1}$, and is measured by the parameter ρ_{v_m,u_m} in the correlation matrix P of reduced-form innovations $\mathbf{u}_t$. We may express the monetary self-feedback as $\phi_{21}\lambda + \phi_{22}\sqrt{1-\lambda^2}$ in terms of the structural parameters in Φ. Similarly, we may express the fiscal policy self-feedback, i.e., feedback, originally measured by ρ_{v_f,u_f}, from the current fiscal policy disturbance $u_{f,t}$ to next period fiscal policy innovation $v_{f,t+1}$, as ϕ_{11}. The monetary to fiscal cross-feedback , i.e., the feedback from $u_{m,t}$ to $v_{f,t+1}$, originally measured by ρ_{v_f,u_m}, can now be expressed as $\phi_{11}\lambda + \phi_{12}\sqrt{1-\lambda^2}$, while the fiscal to monetary cross-feedback, i.e., the feedback from $u_{f,t}$ to $v_{m,t+1}$, originally measured by ρ_{v_m,u_f}, by ϕ_{21}. Contemporaneous policy coordination can also be expressed exactly in the same way as $\phi_{23}\sqrt{1-\phi_{21}^2-\phi_{22}^2}$.

Through the one-to-one mapping between the covariance matrix P and the contemporaneous response matrix Φ, we recover the estimates of the parameters $(\lambda, \phi_{11}, \phi_{12}, \phi_{21}, \phi_{22}, \phi_{23})$ in Φ from the ML estimates of the parameters $(\rho_{u_m,u_f}, \rho_{u_m,v_m}, \rho_{u_m,v_f}, \rho_{u_f,v_m}, \rho_{u_f,v_f}, \rho_{v_m,v_f})$ in P. The following equation presents the estimated version of the structural VAR model (12) defined with the recovered values of $(\lambda, \phi_{11}, \phi_{12}, \phi_{21}, \phi_{22}, \phi_{23})$

$$u_{f,t} = e_{f,t} \tag{13}$$
$$u_{m,t} = 0.155e_{f,t} + 0.988e_{m,t} \tag{14}$$
$$v_{f,t+1} = 0.175e_{f,t} + 0.699e_{m,t} + 0.693\varepsilon_{f,t+1} \tag{15}$$
$$v_{m,t+1} = 0.409e_{f,t} + 0.809e_{m,t} + 0.422\varepsilon_{f,t+1} + 0.008\varepsilon_{m,t+1}. \tag{16}$$

We observe that 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 both 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 may interpret the observed strong response of fiscal policy factor innovation to a positive monetary policy shock as a systematic response of fiscal policy to an increase in interest rate reflecting its concern for interest payment burden and debt stabilization. The substantial response of fiscal policy factor innovation $v_{f,t+1}$ to fiscal policy factor shock $\varepsilon_{f,t+1}$ reflects that a policy factor shock orthogonal to the policy disturbances plays an important role in determining fiscal policy regime. The weak response of fiscal policy factor innovation $v_{f,t+1}$ to fiscal policy shock $e_{f,t}$, 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 shock $e_{f,t}$ and fiscal policy factor shock $\varepsilon_{f,t+1}$, but does not react to monetary policy factor shock $\varepsilon_{m,t+1}$. This implies that monetary factor shock contributes very little to the monetary policy factor innovation, and contemporaneous change in monetary policy factor is driven mostly by two policy shocks and fiscal policy factor shock.

In the next subsection, we present 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 $\mathbf{e}_t = (e_{f,t},\, e_{m,t},\, \varepsilon_{f,t+1},\, \varepsilon_{m,t+1})'$. 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

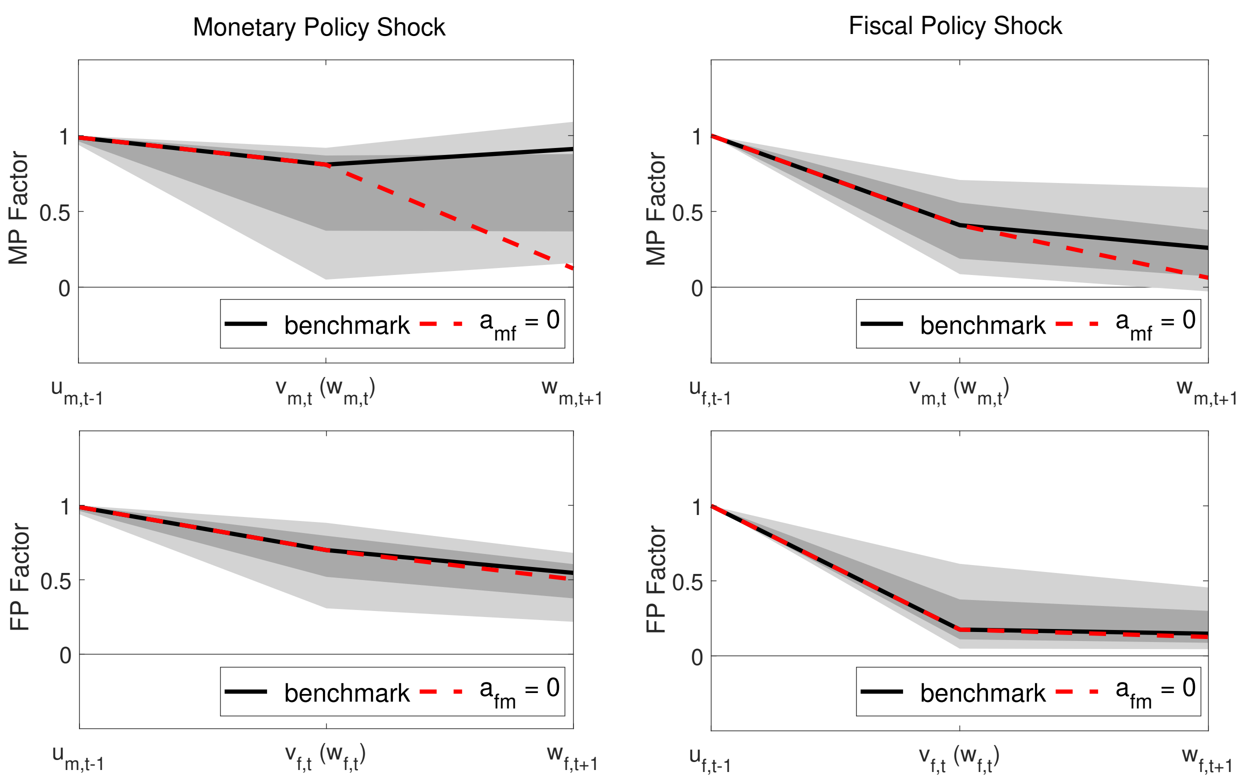
$$w_t = A^t w_0 + \sum_{k=0}^{t-1} A^k v_{t-k} = A^t w_0 + \sum_{k=0}^{t-1} A^k \Phi_2 \mathbf{e}_{t-k}$$

which shows how each of the four structural shocks in $\mathbf{e}_t$ propagates to the monetary and fiscal policy factors in w_t through the AR coefficient matrix A, defining the law of motion for the bivariate policy factor w_t, and the submatrix Φ_2 of Φ, representing contemporaneous responses of policy factor innovations v_{t+1} to all four structural shocks in $\mathbf{e}_t$. The elements in the matrices A and Φ_2 measure the three channels of monetary and fiscal policy interactions introduced earlier.

4.2 Impulse Response Analysis

In this section, we present impulse responses of monetary and fiscal policy factors to the four orthogonal shocks identified from policy disturbances and policy factor innovations, and conduct counterfactual analyses. Figures 4-8 plot the benchmark impulse responses of policy factors to one-unit positive shocks[30] and counterfactual responses obtained by shutting down one of the three policy interaction channels. In our exercises, a positive response of monetary policy factor means the central bank's move toward a hawkish regime, and a positive response of fiscal policy factor means the fiscal authority's move toward a hawkish regime. Since changes in policy factors do not necessarily shift policy regimes, these effects can be considered as updates in policy makers' information set or attitude without necessitating a change in the future policy rules.

Figure 4: Transmission of Policy Shocks to Policy Factors: Dynamic Interaction



Notes: The left (right) column presents the transmission of monetary (fiscal) policy shock at $t-1$ to monetary and fiscal policy factors. The solid black lines show the benchmark dynamics of policy factors, and dashed red lines are for the counterfactual dynamics of policy factors obtained by shutting down dynamic interaction. The second half of each figure on the top (bottom) row shows the counterfactual responses of monetary (fiscal) policy factor at $t+1$ to the fiscal (monetary) policy factor at t obtained by restricting the dynamic interaction parameter a_{mf} (a_{fm}) at zero. The dark and light gray shaded areas, respectively, indicate 68% and 90% confidence intervals for the benchmark case.

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

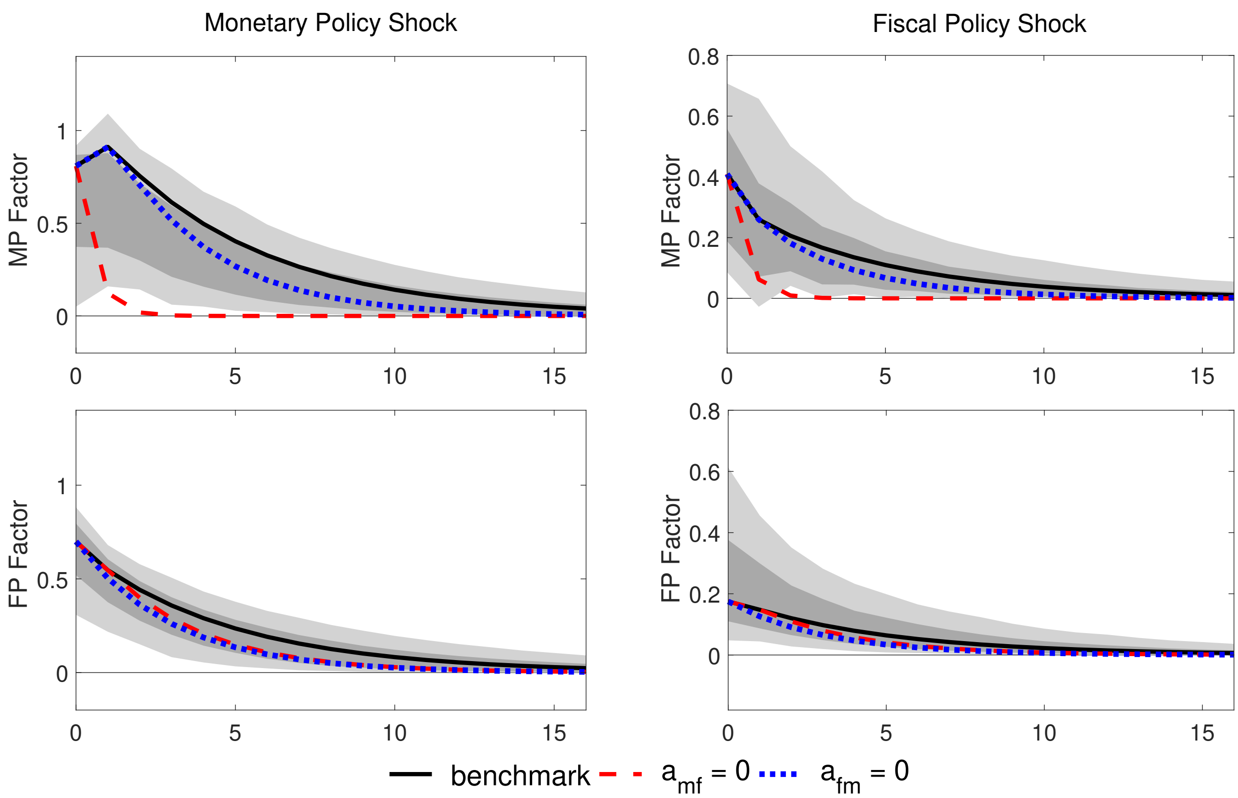
We first focus on the short-term effects of monetary and fiscal policy shocks on policy factors. Between the two policy shocks, our results attribute a more important role to monetary policy shock in driving the short-term policy coordination. Figure 4 traces the benchmark and counterfactual effects of monetary and fiscal policy shocks on policy factors from $t-1$ to $t+1$. Remarkably, the benchmark shows that both policy factors respond positively to both policy shocks. A large enough positive policy shock, monetary or fiscal, pushes the two policy factors in the same direction, resulting in a doubly-hawkish mix. However, concerning the magnitude of the effect, a monetary policy shock $e_{m,t-1}$ produces much larger effects than a fiscal policy shock. A positive one-unit $e_{m,t-1}$ shock results in an immediate 0.99 increase in the monetary policy disturbance $u_{m,t-1}$ without affecting the fiscal policy disturbance. With $w_{m,t-1}$ and $w_{f,t-1}$ set at zero, the monetary and fiscal factor innovations, $v_{m,t}$ and $v_{f,t}$, which equal $w_{m,t}$ and $w_{f,t}$ in this case, increase substantially by 0.81 and 0.70, respectively. In contrast, a fiscal policy shock $e_{f,t-1}$ generates a much weaker impact on policy factors. As is clear in equation (14), a one-unit positive $e_{f,t-1}$ results in a 0.15 increase in the monetary policy disturbance $u_{m,t-1}$. The fiscal policy factor next period $w_{f,t}$ increases only by 0.17, which is about one-quarter in size compared to the effect of a monetary policy shock. We also observe a relatively small increase of size 0.41 in the response of monetary factor $w_{m,t}$ to a fiscal policy shock, which is about half the size of its response to the monetary policy shock.

Furthermore, counterfactual responses in Figure 4 quantify the effects of dynamic interaction channels in the short-term shock propagation. This result reveals that the dynamic channel a_{mf} is quantitatively significant for the next period monetary factor. Note that if all future factor innovations are set at zero, the monetary factor in the next period $w_{m,t+1}$ is a linear combination of current monetary and fiscal factors weighted by a_{mm} and a_{mf}. Dashed red lines in the top row of Figure 4 show that, with a_{mf} fixed at zero, the responses of monetary factor to both policy shocks reduce to zero quickly. Similarly, the fiscal factor $w_{f,t+1}$ is a linear combination of current factors weighted by a_{fm} and a_{ff}. However, as the bottom row of Figure 4 shows, the fiscal factor is not substantially affected by shutting down a_{fm}, the channel from the current monetary factor to the next period fiscal factor.

To gauge the effect of the dynamic interaction channel at longer terms, we plot responses of monetary and fiscal policy factors over 16 quarters in Figure 5. The benchmark responses of both policy factors to policy shocks are significant both in the short-run and over longer horizons. Particularly, the responses to a monetary policy shock are about four times larger than those to a fiscal policy shock, reaffirming the relative importance of monetary policy shock illustrated in the preceding trace plot. Both policy factors respond positively, suggesting potential policy coordination that is unobserved. Once again, and perhaps more clearly in the longer term responses, the key to this policy cooperation is a_{mf}. If we shut down a_{mf}, i.e., when monetary authority stops responding to the past fiscal policy factor, monetary factor quickly diminishes while the fiscal factor stays persistently high, and consequently, policy coordination disappears.

Second, we evaluate the impact of endogenous feedback, self-feedback and cross-feedback, on

Figure 5: Impulse Responses of Policy Factors to Policy Shocks: Dynamic Interaction

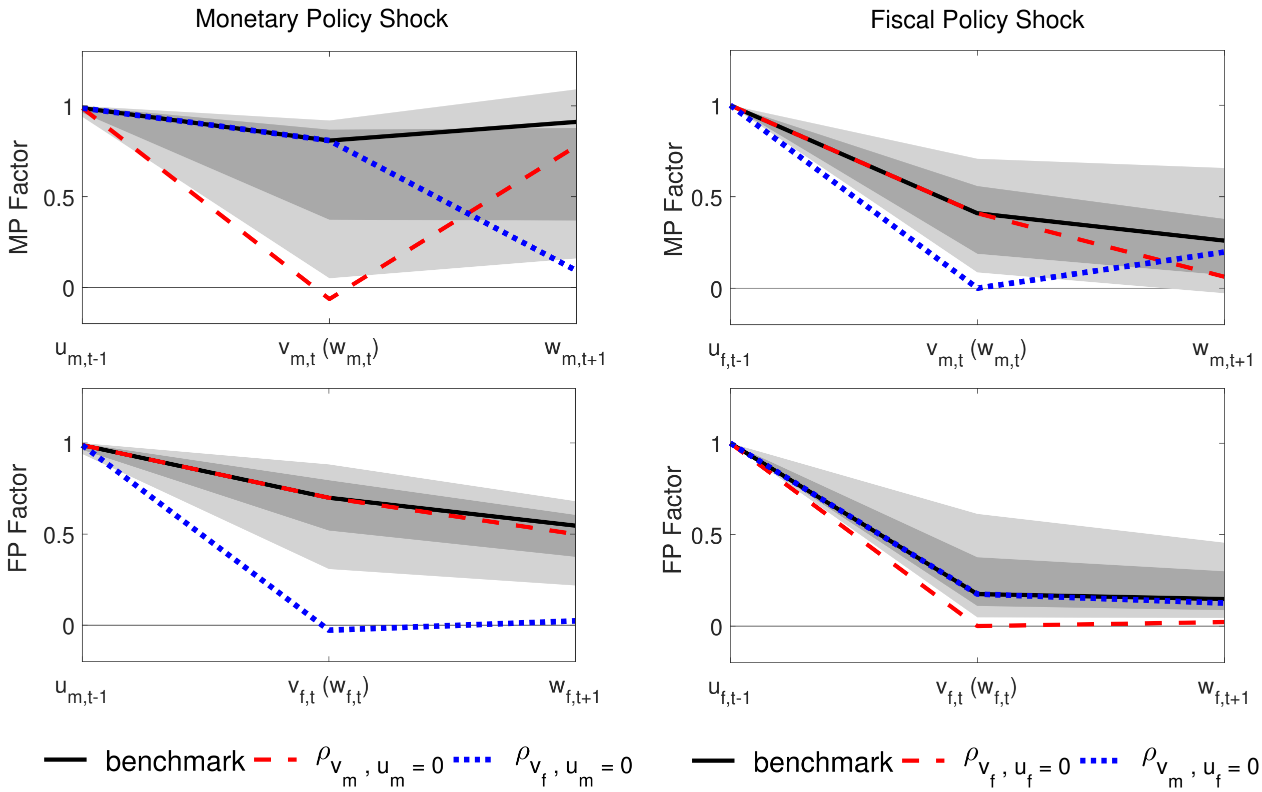


Notes: The left (right) column presents the impulse responses of policy factors to monetary (fiscal) policy shock. Each subfigure includes a benchmark case (solid black line), and two counterfactual cases obtained by shutting down dynamic interaction (1) from current fiscal policy factor to next period monetary policy factor (dashed red line), and (2) from current monetary policy factor to next period fiscal policy factor (dotted blue line). Dark and light shaded areas, respectively, denote 68% and 90% confidence intervals for the benchmark case.

the transmission of policy shocks to policy factors. We start by zooming in on the benchmark and counterfactual responses of both policy factors at t and $t+1$ to policy shocks materialized at $t-1$. Clearly, by comparing the benchmark and counterfactual cases in Figure 6, we observe that the initial responses of monetary and fiscal factors, $w_{m,t}$ and $w_{f,t}$, depend critically on whether or not the fiscal authority adjusts its policy regime in response to the monetary and fiscal policy disturbances, $u_{m,t-1}$ and $u_{f,t-1}$. Specifically, dotted blue lines in the left column of Figure 6 show that when the fiscal factor innovation does not receive feedback from monetary policy disturbance, i.e., when ρ_{v_f,u_m}=0, the fiscal factor does not respond to a monetary policy shock while the monetary factor increases as in the benchmark, implying weaker initial policy coordination.[31] Similarly, dashed red lines in the right column of Figure 6 show that, if the fiscal authority does not react to its own disturbance, i.e., when ρ_{v_f,u_f}=0, the initial policy coordination is also attenuated upon a fiscal policy shock. Analogously, dashed red lines in the left column and dotted blue lines in

[31] If we assume away dynamic interaction with A restricted to be diagonal, this gap will persist for many periods.

Figure 6: Transmission of Policy Shock to Policy Factors: Endogenous Feedback

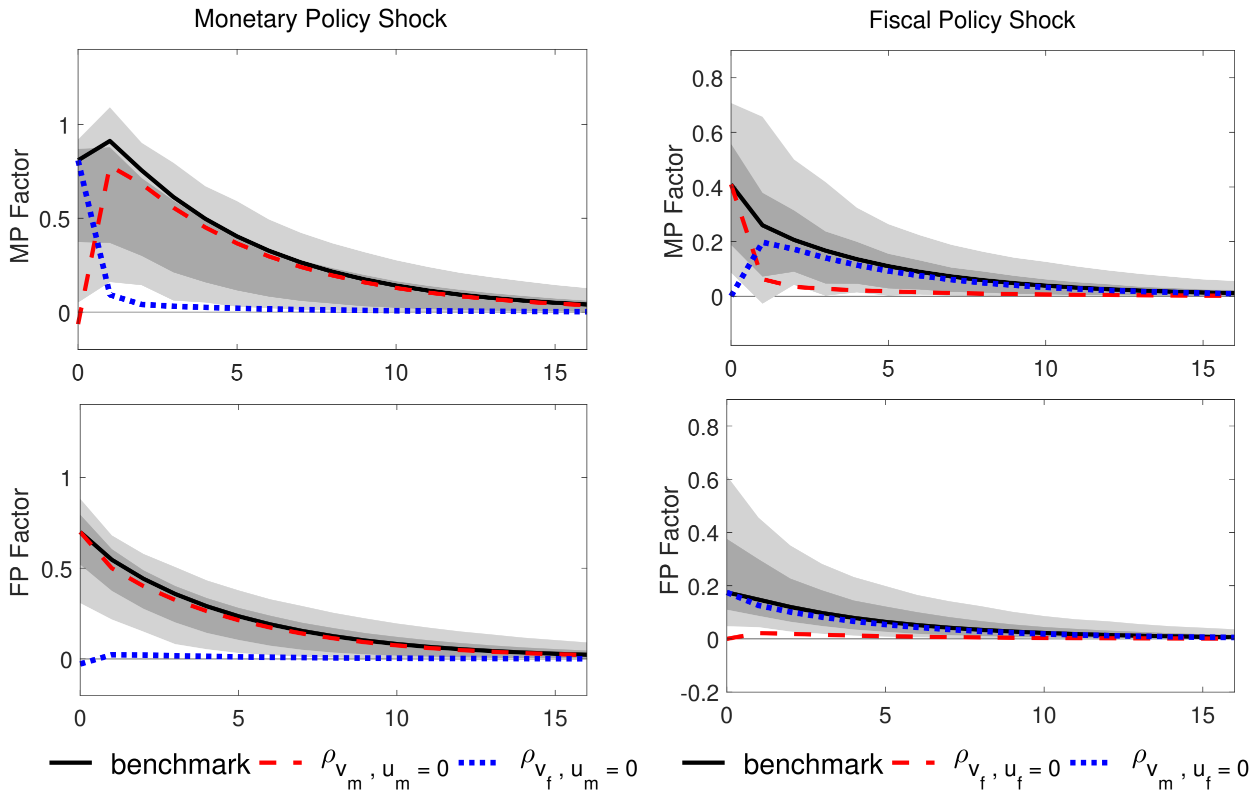


Notes: The left (right) column presents the transmission of monetary (fiscal) policy shock at $t-1$ to policy factors. The top (bottom) row presents the responses of the monetary (fiscal) policy factor to policy shocks. Each subfigure includes benchmark dynamics of policy factors (solid black line), and two counterfactual dynamics obtained by shutting down (1) self-feedback from own policy disturbance at $t-1$ to own policy factor at t and $t+1$ (dashed red line) and (2) cross-feedback from one policy disturbance at $t-1$ to the other policy factor at t and $t+1$ (dotted blue line). The dark and light gray shaded areas, respectively, indicate 68% and 90% confidence intervals for the benchmark case.

the right column show the short-term importance of the feedback channels to monetary factor innovation from the monetary and fiscal policy innovations reflected respectively in ρ_{v_m,u_m} and ρ_{v_m,u_f}. However, as will be clear in the following analysis, these feedback channels to monetary factor do not generate substantial effect at longer horizons.

At longer horizons, feedback channels to the fiscal policy factor innovation appear to be relatively more important than those to the monetary policy factor innovation. Solid black lines in Figure 7 plot the benchmark impulse responses of the policy factors over 16 quarters against the cases in which one of the feedback channels is suppressed. As shown by dotted blue line in the bottom-left panel, if the fiscal policy authority does not adjust its policy stance in respond to a monetary policy disturbance, its policy factor does not react to a monetary policy shock, and the magnitudes of responses are negligible at all horizons, with all else being equal. In this case, the monetary factor responds to a monetary policy shock initially but reduces to zero after a few quarters upon the shock,

Figure 7: Impulse Responses of Policy Factors to Policy Shocks: Endogenous Feedback

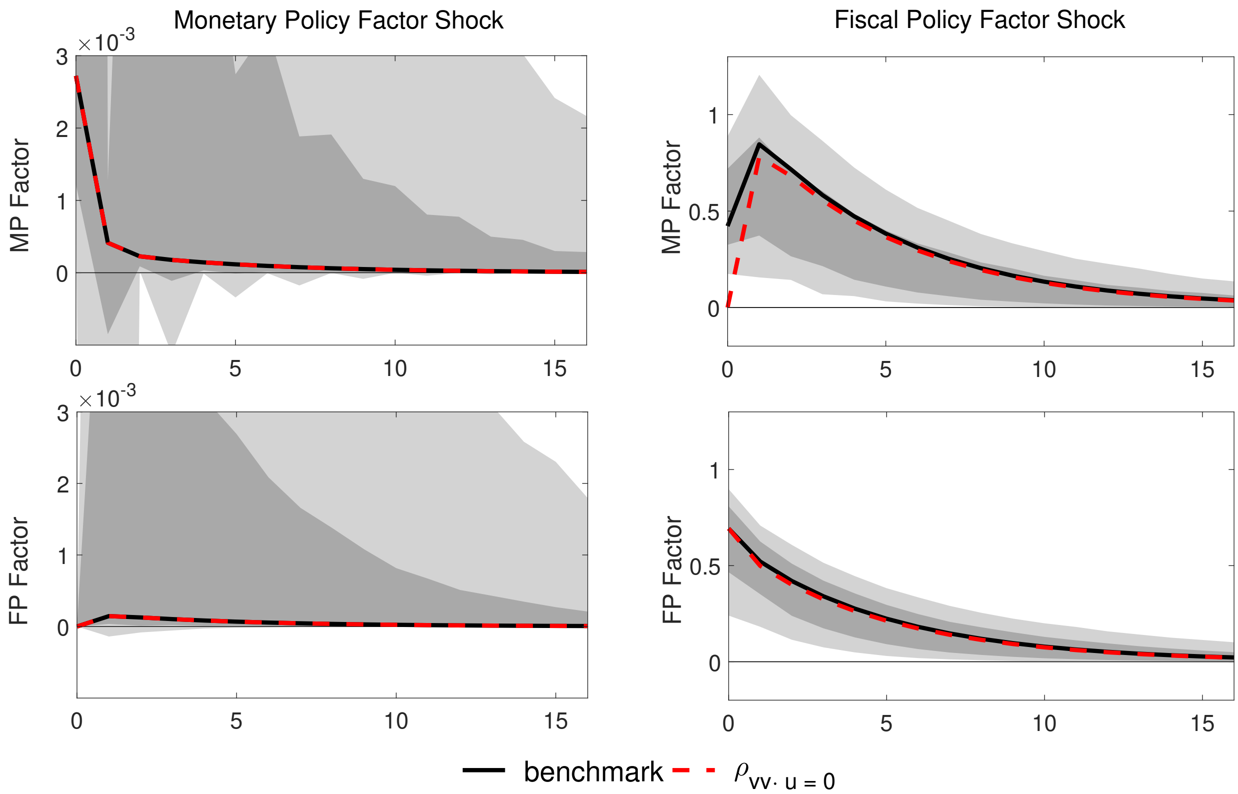


Notes: The left (right) column presents impulse responses of policy factors to monetary (fiscal) policy shocks. Each subfigure includes a benchmark case (solid black line), and two counterfactual impulse responses obtained by shutting down (1) self-feedback from past own policy disturbance to current own policy factor (dashed red line) and (2) cross-feedback from past one policy disturbance to current other policy factor (dotted blue line). Dark and light shaded areas, respectively, present 68% and 90% confidence intervals for the benchmark case.

as shown by the dotted blue line in the top-left panel. Therefore, without the cross-feedback to fiscal factor from a monetary policy disturbance, the monetary policy shock is not able to generate persistent changes in the monetary policy factor. Similarly, if the fiscal authority is inattentive to a past fiscal policy shock, i.e., when we shut down fiscal self-feedback channel, coordination between two policy authorities is negligible and only short-lasting, as shown by dashed red lines in the right column of Figure 7. On the other hand, even if the central bank does not update its policy factor immediately in response to either monetary or fiscal disturbances, i.e., when ρ_{v_m,u_m}=0 or ρ_{v_m,u_f}=0, once the fiscal authority updates its policy factor, monetary policy authority will likely adjust its policy regime with a lag and remain cooperative.

Lastly, Figure 8 presents the impulse responses of policy factors to policy factor shocks, $\varepsilon_t = (\varepsilon_{m,t}, \varepsilon_{f,t})$. Under our recursive identification scheme, the fiscal factor shock $\varepsilon_{f,t}$ influences both policy factor innovations, $v_{f,t}$ and $v_{m,t}$, while the monetary factor shock $\varepsilon_{m,t}$ affects only monetary policy factor innovation $v_{m,t}$. Recall that correlation between the two policy factor shocks, $\rho_{vv \cdot u}$,

Figure 8: 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 (solid black line), and counterfactual impulse response obtained by shutting down a contemporaneous policy coordination, $\rho_{vv\cdot u}$=0 (dashed red line). Dark and light shaded areas, respectively, present 68% and 90% confidence intervals for the benchmark case.

generates contemporaneous policy coordination. To see how much this contemporaneous policy coordination channel contributes to the interaction of policy factors, we obtain counterfactual responses of policy factors to monetary and fiscal policy factor shocks with $\rho_{vv\cdot u}$ suppressed, which are presented by the dashed red lines, respectively, in the left and right columns of Figure 8. Clearly, the fiscal factor shock $\varepsilon_{f,t}$ plays a quantitatively much more significant role than its monetary counterpart $\varepsilon_{m,t}$ in generating the contemporaneous policy coordination. Moreover, if the central bank does not immediately adjust its policy factor to the fiscal factor shock, the two authorities fail to coordinate their policy regimes at impact. However, due to the significant dynamic interaction between two policy factors and strong endogenous feedback, we still observe substantial interaction between monetary and fiscal policies in the longer horizons.

The counterfactual impulse response analyses present additional insights on the strong positive comovements of monetary and fiscal policy factors. Both monetary and fiscal policy shocks and dynamic interaction from fiscal policy regime to monetary policy critically matter for both short-term and longer term policy interactions. In contrast to previous empirical studies, our findings are well aligned with the effectiveness of fiscal policy in the policy mix determination emphasized in theoretical discussions about monetary-fiscal policy interaction.

5 Conclusion

We report a large set of empirical findings that suggest strong interactions in postwar U.S. monetary and fiscal policies. To that end, we investigate monetary and fiscal policy interactions in a regime-switching model of monetary and fiscal policy rules where policy regimes are determined by a latent bivariate autoregressive process consisting of monetary and fiscal policy factors. Specifically, we propose three measures of interaction between policy authorities, namely endogenous feedback, dynamic interaction, and contemporaneous coordination.

Among our empirical findings, we highlight three results that offer novel insights concerning U.S. monetary and fiscal policy interactions. First, there is a strong dynamic interaction between monetary and fiscal policy factors, which implies that changes in one policy regime help to predict changes in the other policy regime. In particular, we find that the most substantial and persistent policy coordination is generated by the strong dynamic interaction channel bridging a fiscal policy factor to the future monetary policy factor. Second, we identify the most important feedback channels to be those through which monetary policy disturbances influence future monetary and fiscal policy regimes, and therefore a policy mix. Third, we document a considerable level of contemporaneous coordination between the two policy authorities which captures their contemporaneous cooperative adjustments in policy regimes net of feedback effects from past policy actions. We also augment these findings with adaptive LASSO to identify the common drivers of policy factors, and frequency domain analyses to quantity the effects of these channels on policy coordination across different frequencies.

References

Aiyagari, R., Gertler, M., 1985. The Backing of Government Bonds and Monetarism. Journal of Monetary Economics 16 (1), 19–44.

Auerbach, A. J., 2003. Fiscal Policy, Past and Present. Brookings Papers on Economic Activity (1), 75–122.

Ballabriga, F. C., Martinez-Mongay, C., 2005. Sustainability of EU Public Finances. European Commission Economic Papers 225.

Barthélemy, J., Marx, M., 2017. Solving Endogenous Regime Switching Models. Journal of Economic Dynamics and Control 77, 1–25.

Bianchi, F., 2012. Evolving Monetary/Fiscal Policy Mix in the United States. The American Economic Review 102 (3), 167–172.

Bianchi, F., Ilut, C., 2017. Monetary/Fiscal Policy Mix and Agent's Beliefs. Review of Economic Dynamics 26, 113–139.

Bianchi, F., Melosi, L., 2014. Dormant Shocks and Fiscal Virtue. NBER Macroeconomics Annual 28 (1), 1–46.

Bianchi, F., Melosi, L., 2017. Escaping the Great Recession. American Economic Review 107 (4), 1030–1058.

Bianchi, F., Melosi, L., 2019. The Dire Effects of the Lack of Monetary and Fiscal Coordination. Journal of Monetary Economics 104, 1–22.

Blanchard, O., Perotti, R., 2002. An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. The Quarterly Journal of Economics 117 (4), 1329–1368.

Board of Governors of the Federal Reserve System, 1993. Transcript of Federal Open Market Committee, (March 23).

Bohn, H., 1998. The Behavior of U.S. Public Debt and Deficits. The Quarterly Journal of Economics 113, 949–963.

Chang, Y., Choi, Y., Park, J. Y., 2017. A New Approach to Model Regime Switching. Journal of Econometrics 196 (1), 127–143.

Chang, Y., Park, J. Y., Qiu, S., 2020. Regime Switching Models with Multiple Dynamic Factors. Working paper, Indiana University.

Chung, H., Davig, T., Leeper, E. M., 2007. Monetary and Fiscal Policy Switching. Journal of Money, Credit and Banking 39 (4), 809–842.

Claeys, P., 2004. Monetary and Budgetary Policy Interaction: An SVAR Analysis of Stabilization Policies in Monetary Union. Working paper, European University Institute.

Cohen, D. S., Follette, G. R., 2005. Forecasting Exogenous Fiscal Variables in the United States. Fianace and Economics Discussion Series 2003-2059, Federal Reserve Board.

Davig, T., 2004. Regime-Switching Debt and Taxation. Journal of Monetary Economics 51 (4), 837–859.

Davig, T., Leeper, E. M., 2006a. Endogenous Monetary Policy Regime Change. In: Reichlin, L. and West, K.D. (Ed.), NBER International Seminar on Macroeconomics 2006. University of Chicago Press, pp. 345–391.

Davig, T., Leeper, E. M., 2006b. Fluctuating Macro Policies and the Fiscal Theory. In: Acemoglu, D., Rogoff, K. and Woodford, M. (Ed.), NBER Macroeconomics Annual 2006, Volume 21. MIT Press, pp. 247–316.

Efron, B., Tibshirani, R. J., 1993. An Introduction to the Bootstrap. Chapman & Hall/CRC.

Ettmeier, S., Kriwoluzky, A., 2020. Active, or Passive? Revisiting the Role of Fiscal Policy in the Great Inflation. Discussion Papers 1872, DIW Berlin.

Fatás, A., Mihov, I., 2001. The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence. CEPR Discussion Papers 2760.

Favero, C. A., Monacelli, T., 2005. Fiscal Policy Rules and Regime (In)Stability: Evidence from the U.S. Working Paper 282, IGIER.

Gonzalez-Astudillo, M., 2013. Monetary-Fiscal Policy Interactions: Interdependent Policy Rule Coefficients. Finance and Economics Discussion Series 2013–2058, Federal Reserve Board.

Gonzalez-Astudillo, M., 2018. Identifying the Stance of Monetary Policy at the Zero Lower Bound: A Markov-Switching Estimation Exploiting Monetary-Fiscal Policy Interdependence. Journal of Money, Credit and Banking 50 (1), 115–154.

Kim, C.-J., 1 2009. Markov-Switching Models with Endogenous Explanatory Variables II: A Two-step MLE Procedure. Journal of Econometrics 148, 46–55.

King, M., 1995. Commentary: Monetary Policy Implications of Greater Fiscal Discipline. In: Budget Deficits and Debt: Issues and Options. Federal Reserve Bank of Kansas City Economic Conference Proceedings, Jackson Hole Symposium, pp. 171–183.

King, R. G., Plosser, C. I., 1985. Money, Deficits, and Inflation. Carnegie-Rochester Conference Series on Public Policy 22 (1), 147–195.

Kliem, M., Kriwoluzky, A., Sarferaz, S., 2016a. Monetary-Fiscal Policy Interaction and Fiscal Inflation: A Tale of Three Countries. European Economic Review 88, 158–184.

Kliem, M., Kriwoluzky, A., Sarferaz, S., 2016b. On the Low-Frequency Relationship between Public Deficits and Inflation. Journal of Applied Econometrics 31 (3), 566–583.

Leeper, E. M., 1991. Equilibria Under 'Active' and 'Passive' Monetary and Fiscal Policies. Journal of Monetary Economics 27 (1), 129–147.

McCracken, M., Ng, S., 2020. FRED-QD: A Quarterly Database for Macroeconomic Research. Working Paper 26872, National Bureau of Economic Research.

McIlhagga, W., 2016. Penalized: A MATLAB Toolbox for Fitting Generalized Linear Models with Penalties. Journal of Statistical Software 72 (6), 1–21.

Melitz, J., 1997. Some Cross-Country Evidence about Debt, Deficits and the Behaviour of Monetary and Fiscal Authorities. CEPR Discussion Paper 1653.

Melitz, J., 2000. Some Cross-Country Evidence about Fiscal Policy Behavior and Consequences for EMU. Unpublished Manuscript.

Mountford, A., Uhlig, H., 2009. What are the Effects of Fiscal Policy Shocks? Journal of Applied Econometrics 24 (6), 960–992.

Muscatelli, A., Tirelli, P., Trecroci, C., 2002. Monetary and Fiscal Policy Interactions over the Cycle: Some Empirical Evidence. CESifo Working Paper Series 817, CESifo Group Munich.

Pechman, J., 1987. Federal Tax Policy. Fifth Ed. The Brookings Institution, Washington, D.C. .

Politis, D., White, H., 2004. Automatic Block-Length Selection for the Dependent Bootstrap. Econometric Reviews 23 (1), 53–70.

Politis, D. N., Romano, J. P., 1994. The Stationary Bootstrap. Journal of the American Statistical Association 89 (428), 1303–1313.

Poterba, J., 1994. Federal Budget Policy in the 1980s. In: Feldstein, M. (Ed.), American Economic Policy in the 1980s, University of Chicago Press, Chicago, IL. MIT Press, Cambridge, MA, pp. 235–270.

Romer, C. D., Romer, D. H., 2004. Choosing the Federal Reserve Chair: Lessons from History. Journal of Economic Perspectives 18 (1), 129–162.

Sargent, T. J., Wallace, N., 1981. Some Unpleasant Monetarist Arithmetic. Quarterly Review (Fall).

Sims, C. A., 1988. Identifying Policy Effects. In: Bryant, R.C. et al (Ed.), Empirical Macroeconomics for Interdependent Economics. The Brookings Institution, Washington, D.C., pp. 308–321.

Sims, C. A., Zha, T., 2006. Were There Regime Switches in U.S. Monetary Policy? American Economic Review 96 (1), 54–81.

Stein, H., 1996. In: The Fiscal Revolution in America. Second Revised Ed. AEI Press, Washington, D.C.

Steuerle, C., 2002. Tax Policy from 1990 to 2001. In: J. Frankel, and Orszag, P. (Ed.), American Economic Policy in the 1990s, MIT Press, Cambridge, MA. pp. 139–169.

Tan, F., 2019. A Frequency-Domain Approach to Dynamic Macroeconomic Models. Macroeconomic Dynamics , 1–31.

Taylor, J. B., 1993. Discretion versus Policy Rules in Practice. Carnegie-Rochester Conference Series on Public Policy 39 (1), 195–214.

Taylor, J. B., 2000. Reassessing Discretionary Fiscal Policy. Journal of Economic Perspectives 14 (3), 21–36.

Tibshirani, R., 1996. Regression Shrinkage and Selection Via the Lasso. Journal of the Royal Statistical Society, Series B 58, 267–288.

Unsigned, 2005a. Still Gushing Forth. The Economist, (February 3) .

Unsigned, 2005b. Saturated. The Economist, (February 24) .

von Jagen, J., Hallett, A. H., Strauch, R., 2001. Budgetary Consolidation in EMU. Economic Papers 148, European Commission Brussels.

Wallace, N., 1981. A Modigliani-Miller Theorem for Open-Market Operations. The American Economic Review 71 (3), 267–274.

Wu, J. C., Xia, F. D., 2016. Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound. Journal of Money, Credit, and Banking 48 (2-3), 253–291.

Yang, S.-C. S., 2007. Tentative Evidence of Tax Foresight. Economics Letters 96 (1), 30–37.

Zou, H., 2006. The Adaptive Lasso and Its Oracle Properties. Journal of the American Statistical Association 101, 1418–1429.

Appendix A: Robustness Checks

A.1: Comparisons of Alternative Model Specifications

We compare estimates from our baseline regime-switching policy rules with those from alternative specifications. We consider the effects of alternative specifications in the policy regime factors and of the smoothing components in policy rules. The first three columns of Table 3 collect estimates of regime-switching policy rules with restricted policy regime factors (Models 1,2 and 3), and the last column presents estimates of regime-switching policy rules without smoothing components (Model 4). Specifications of autoregressive coefficient matrix A and correlation coefficient matrix P are essential to capture the dynamics of policy regime factors through endogenous feedback, dynamic interaction, and contemporaneous policy coordination. For comparisons, we impose restrictions on the matrices A and P and consider three alternative specifications: (1) equation by equation estimation of exogenous regime-switching monetary and fiscal policy rules with zero restrictions on the off-diagonals in the matrices A and P; (2) joint estimation of exogenous regime-switching policy rules with the same zero restrictions on the off-diagonals of the matrix P; (3) joint estimation of regime-switching policy rules without cross-feedback channels by imposing zero restrictions on the relevant elements of the matrix P. We observe that with these restrictions on policy regime factors, fiscal policy regimes are not as clearly distinguishable with wider confidence intervals compared to the baseline model. We also note that restrictions on policy regime factor dynamics may lead to different interpretations of policy rule coefficients and inferences on channels of policy interaction.

Lastly, we turn to the effect 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 results. We observe that each policy authority strongly responds to its own past policy regime while its response to the other policy authority's past policy regime is muted. Concerning policy rule coefficients, without a smoothing component in the monetary policy rule, we still observe two interpretable monetary policy regimes, but differences between these policy regimes become less distinguishable. For the fiscal policy rule without a smoothing component, we obtain two distinguishable regimes in terms of responses to output and government spending, but not the responses to debt. We observe a significant decline in the log likelihood of the restricted models compared to our baseline specification, especially of the model without smoothing components.

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	[-2.231,3.338]	3.829	[-4.319,7.980]	0.724	[-1.682,2.331]	5.994	[-8.272,9.994]
ψ_f	-2.080	[-3.756,-1.279]	-2.172	[-4.456,-1.636]	-2.898	[-6.000,-2.059]	-4.038	[-9.991,9.993]
a_{mm}	0.963	[0.683,0.979]	0.694	[0.114,0.983]	0.936	[0.626,1.029]	0.994	[0.642,0.994]
a_{fm}	-	-	0.000	[-0.016,1.161]	0.496	[0.278,2.737]	0.000	[-0.062,0.219]
a_{mf}	-	-	1.809	[-0.341,3.996]	0.000	[-0.257,0.079]	0.000	[-0.813,0.359]
a_{ff}	0.772	[0.046,0.918]	0.776	[0.136,0.839]	0.245	[-0.602,0.636]	0.995	[-0.107,0.995]
ρ_{u_m,u_f}	-	-	-	-	-	-	0.454	[0.344,0.547]
ρ_{v_m,u_m}	-	-	-	-	0.749	[0.016,0.995]	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	[-0.431,0.997]	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	[0.694,0.889]	0.785	[0.719,0.879]	0.725	[0.662,0.895]	-	-
$\alpha_{\rho,1}$	0.654	[0.392,0.959]	0.696	[0.437,0.952]	0.753	[0.513,0.941]	-	-
$\alpha_{c,0}$	2.233	[-0.703,4.080]	2.444	[-0.135,3.899]	1.635	[-0.064,3.725]	1.377	[1.190,1.690]
$\alpha_{c,1}$	2.332	[-2.295,3.815]	1.994	[-0.763,3.333]	1.396	[-0.975,3.178]	3.469	[-0.781,3.852]
$\alpha_{\pi,0}$	0.561	[0.006,0.748]	0.514	[0.006,0.700]	0.631	[0.021,0.717]	0.792	[0.761,0.807]
$\alpha_{\pi,1}$	1.477	[0.965,3.793]	1.533	[1.094,3.002]	1.786	[0.842,2.849]	1.101	[0.820,1.413]
$\alpha_{y,0}$	0.576	[0.068,1.011]	0.609	[0.062,0.955]	0.447	[0.105,0.906]	0.347	[0.284,0.409]
$\alpha_{y,1}$	-0.188	[-0.469,1.052]	-0.262	[-0.514,0.980]	-0.025	[-0.415,0.853]	0.011	[-0.239,0.581]
α_η^π	0.089	[0.019,0.144]	0.092	[0.014,0.141]	0.099	[0.015,0.146]	-0.061	[-0.217,0.095]
α_η^y	0.058	[-0.055,0.133]	0.071	[-0.038,0.142]	0.062	[-0.044,0.132]	-0.139	[-0.279,-0.014]
σ_m	0.459	[0.272,0.538]	0.456	[0.269,0.542]	0.455	[0.276,0.549]	1.002	[0.893,1.080]
$\beta_{\rho,0}$	0.139	[0.000,0.327]	0.140	[0.002,0.290]	0.159	[0.002,0.424]	-	-
$\beta_{\rho,1}$	0.948	[0.851,0.956]	0.948	[0.850,0.956]	0.952	[0.858,0.959]	-	-
$\beta_{c,0}$	3.366	[2.987,3.872]	3.343	[2.964,3.765]	3.340	[2.879,3.707]	4.355	[2.980,4.644]
$\beta_{c,1}$	2.017	[1.095,3.134]	2.037	[1.179,3.111]	1.967	[1.217,2.967]	1.176	[1.129,1.316]
$\beta_{b,0}$	0.085	[0.081,0.087]	0.085	[0.085,0.086]	0.090	[0.090,0.090]	-0.012	[-0.012,-0.012]
$\beta_{b,1}$	0.127	[0.086,0.183]	0.127	[0.085,0.176]	0.139	[0.090,0.174]	-0.012	[-0.012,-0.012]
$\beta_{y,0}$	0.329	[0.259,0.438]	0.326	[0.258,0.419]	0.317	[0.258,0.411]	0.336	[-0.164,0.586]
$\beta_{y,1}$	0.294	[0.122,0.423]	0.291	[0.126,0.416]	0.297	[0.125,0.432]	0.080	[0.064,0.111]
$\beta_{g,0}$	-0.343	[-0.436,-0.304]	-0.343	[-0.409,-0.314]	-0.367	[-0.398,-0.359]	-0.206	[-0.206,-0.206]
$\beta_{g,1}$	-0.064	[-0.338,0.182]	-0.071	[-0.314,0.170]	-0.076	[-0.295,0.111]	0.357	[0.357,0.357]
β_η^y	0.023	[-0.005,0.038]	0.023	[-0.002,0.039]	0.024	[0.000,0.039]	-0.084	[-0.116,-0.053]
σ_f	0.137	[0.110,0.149]	0.137	[0.114,0.153]	0.137	[0.113,0.152]	0.258	[0.242,0.273]
log likelihood	-84.193		-81.233		-75.079		-332.516	

Notes: Table 3 reports 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 a regime-switching model without cross-feedback channels, and (4) joint estimation of a regime-switching model without smoothing components in policy rules. All missing values (-) are zeros.

A.2: Specification with State-Invariant Coefficients

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

Table 4: Estimation Results for 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	[0.677,0.974]	$\beta_{\rho,0}$	0.114	[0.005,0.239]	ψ_m	0.844	[-0.562,2.243]
			$\beta_{\rho,1}$	0.955	[0.940,0.971]	ψ_f	-2.453	[-3.563,-1.672]
α_c	1.833	[-7.026,3.083]	$\beta_{c,0}$	3.301	[2.973,3.457]	a_{mm}	0.226	[-0.274,0.539]
			$\beta_{c,1}$	2.359	[1.780,3.038]	a_{fm}	0.054	[-0.071,0.179]
$\alpha_{\pi,0}$	0.586	[0.008,0.617]	$\beta_{b,0}$	0.082	[0.082,0.082]	a_{mf}	1.078	[0.140,1.500]
$\alpha_{\pi,1}$	1.639	[1.342,6.920]	$\beta_{b,1}$	0.193	[0.162,0.224]	a_{ff}	0.719	[0.532,0.813]
$\alpha_{y,0}$	0.422	[-0.531,0.766]	β_y	0.340	[0.277,0.387]	$\rho_{u_m u_f}$	0.128	[0.019,0.300]
$\alpha_{y,1}$	-0.042	[-0.433,0.895]				$\rho_{v_m u_m}$	0.838	[0.203,0.927]
α_η^π	0.126	[0.001,0.204]	$\beta_{g,0}$	-0.309	[-0.309,-0.301]	$\rho_{v_f u_m}$	0.701	[0.297,0.899]
α_η^y	0.047	[-0.047,0.140]	$\beta_{g,1}$	-0.308	[-0.309,-0.301]	$\rho_{v_m u_f}$	0.329	[-0.044,0.684]
σ_m	0.467	[0.326,0.560]	β_η^y	0.026	[-0.006,0.041]	$\rho_{v_f u_f}$	0.156	[0.055,0.592]
			σ_f	0.137	[0.121,0.153]	$\rho_{v_m v_f}$	0.938	[0.532,0.971]
						$\rho_{vv\cdot u}$	0.336	[0.064,0.680]
log likelihood				-68.442				

A.3: The Presence of Zero Lower Bound (ZLB)

For a robustness check, we use the estimated shadow rates from Wu and Xia (2016) to construct an alternate policy rate i_t^* by splicing together the T-bill rate i_t until t =2008:Q4 and the estimated shadow rate $\hat{i}_t$ from t =2009:Q1.[32]

Table 5: Estimation Results using Shadow Rates from 2009:Q1

Monetary Policy			Fiscal Policy			Regime Factor Dynamics		
Parameter	Estimate	90% CI	Parameter	Estimate	90% CI	Parameter	Estimate	90% CI
$\alpha_{\rho,0}$	0.790	[0.704,0.915]	$\beta_{\rho,0}$	0.126	[0.001,0.188]	ψ_m	0.725	[-1.150,2.725]
$\alpha_{\rho,1}$	0.790	[0.669,0.962]	$\beta_{\rho,1}$	0.944	[0.897,0.960]	ψ_f	-2.554	[-3.554,-1.679]
$\alpha_{c,0}$	1.658	[-0.876,3.748]	$\beta_{c,0}$	3.301	[3.145,3.395]	a_{mm}	-0.169	[-0.544,0.331]
$\alpha_{c,1}$	1.078	[-1.047,2.420]	$\beta_{c,1}$	1.845	[1.470,2.314]	a_{fm}	0.054	[-0.071,0.118]
$\alpha_{\pi,0}$	0.595	[0.157,0.657]	$\beta_{b,0}$	0.085	[0.085,0.085]	a_{mf}	1.336	[0.273,1.606]
$\alpha_{\pi,1}$	1.875	[1.417,2.924]	$\beta_{b,1}$	0.121	[0.098,0.129]	a_{ff}	0.777	[0.683,0.840]
$\alpha_{y,0}$	0.618	[0.118,1.056]	$\beta_{y,0}$	0.342	[0.326,0.373]	$\rho_{u_m u_f}$	0.196	[0.055,0.368]
$\alpha_{y,1}$	-0.010	[-0.456,1.041]	$\beta_{y,1}$	0.291	[0.166,0.416]	$\rho_{v_m u_m}$	0.807	[0.258,0.986]
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	[0.312,0.964]
α_η^y	0.061	[-0.049,0.123]	$\beta_{g,1}$	-0.020	[-0.067,0.042]	$\rho_{v_m u_f}$	0.445	[0.046,0.732]
σ_m	0.489	[0.305,0.579]	β_η^y	0.020	[0.004,0.036]	$\rho_{v_f u_f}$	0.205	[0.048,0.555]
			σ_f	0.138	[0.120,0.155]	$\rho_{v_m v_f}$	0.834	[0.605,0.996]
						$\rho_{vv\cdot u}$	0.298	[0.002,0.673]
log likelihood				-78.847				

Table 5 presents the resulting estimates and 90% confidence intervals from the estimation of

[32] As an alternative approach to handle the ZLB period, Gonzalez-Astudillo (2018) proposes 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. He shows that an interdependence between monetary and fiscal policy rules helps identify underlying monetary policy regimes during the ZLB period. This approach can be implemented in our estimation, but we leave this exercise for future work.

our baseline model with the alternate policy rate i_t^*. We find that the new results are consistent with baseline results.

Appendix B: Adaptive LASSO Method

We select macroeconomic variables as the predictors for each of our target variables, i.e., monetary and fiscal policy factors. Our variable selection results reported in Table 2 are based on the adaptive LASSO first proposed by Zou (2006), which extends the original LASSO estimator (Tibshirani, 1996), to select the correct subset of variables with $\sqrt{n}$ estimation rate. Essentially, the adaptive LASSO approach replaces the L_1-regularization in the LASSO objective function with a weighted L_1-penalty term. The weight is given by the inverse of a preliminary estimate of β_i. The adaptive LASSO estimator we use in the paper is

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

where λ is a nonnegative regularization parameter, N the dimension of X, and $|\hat{\beta}_i(\delta)|$ is the adaptive weight. We perform ridge regression in the first stage as suggested in Zou (2006) instead of OLS due to the high level of collinearity among the large number of predictors considered in our analysis. The ridge estimate $\hat{\beta}_i$ is obtained with a properly chosen ridge regression parameter δ. Specifically, we choose δ and λ to minimize the Bayesian Information Criterion (BIC),

$$BIC(\delta, \lambda) = \log(n)\mathrm{df}(\delta, \lambda) - 2\log(L(\delta, \lambda))$$

where $\mathrm{df}(\delta, \lambda)$ is the degree of freedom given by the number of nonzero coefficients, n is the number of observations, and L is the likelihood of the model assuming Gaussian error terms. To this end, we search δ on a fine grid of $(0, 1]$, and for each grid point we minimize BIC with respect to λ. Given the regularization parameters and the corresponding weights, the adaptive LASSO problem is transformed to a standard LASSO problem, and solved using the algorithm implemented in McIlhagga (2016).