Monetary-Fiscal Policy Interactions and Indeterminacy in Post-War U.S. Data

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Using a micro-founded model and a likelihood based inference method, we address three questions in this paper. First, what monetary and fiscal policy regimes characterized post-war U.S. data? Second, was equilibrium indeterminacy a feature of the economy before Paul Volcker's chairmanship at the Federal Reserve? Third, what were the effects of shifts in monetary and fiscal policy on the aggregate economy?

We find that pre-Volcker, a passive monetary and fiscal policy regime prevailed while post-Volcker, an active monetary and passive fiscal policy regime characterized the economy.[1] Since both monetary and fiscal policies were passive pre-Volcker, there was equilibrium indeterminacy.

Moreover, the effects of monetary and fiscal policy shifts on the aggregate economy were substantially different in the two time periods. For example, while pre-Volcker, an unanticipated increase in interest rates led to an increase in output and inflation but a decline in government debt-to-output ratio, post-Volcker, it led to a decline in output and inflation but an increase in debt-to-output ratio. Moreover, while pre-Volcker, an unanticipated increase in the tax revenues-to-output ratio led to a decline in output, inflation, and debt-to-output ratio, post-Volcker, it led to a decline in debt-to-output ratio but had no effects on output or inflation.

The response of the economy pre-Volcker was thus similar to that predicted by the fiscal theory of the price level (FTPL). Following an increase in interest payments due to a contractionary monetary policy, inflation increased to stabilize government debt and shifts in fiscal policy influenced inflation and output. In contrast, post-Volcker, the response of the economy followed the predictions of standard models.

Our main contribution is to provide new insights by jointly considering monetary and fiscal policy interactions and multiplicity of equilibria. In a seminal contribution, Thomas A. Lubik and Frank Schorfheide (2004) assess the role of equilibrium indeterminacy due to passive monetary policy but abstract from fiscal policy. Nora Traum and Shu-Chun S. Yang (2011) tackle monetary and fiscal policy interactions but abstract from the possibility of equilibrium indeterminacy.

I. Model

We use a standard DSGE model with nominal and real rigidities. We lay out the basic model features and introduce relevant notation below.

Households, a continuum in the unit interval, face an infinite horizon problem and maximize expected discounted utility (discount factor given by β) over consumption and leisure. Households are subject to an intertemporal discount factor shock δ_t. The utility function is additively separable over consumption and labor effort, where consumption enters relative to a time-varying external habit variable. We assume a unit intertemporal elasticity of substitution to ensure a balanced growth path. The Frisch elasticity of labor supply is given by φ^{-1} and the degree of habit formation by η.

Firms, a continuum in the unit interval, produce differentiated goods using firm-specific labor as input and a constant returns to scale technology subject to an aggregate technology shock A_t. The elasticity of substitution over the differentiated goods is stochastic and given by θ_t. Firms have some monopoly power over setting prices, which are sticky in nominal terms. Price

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[1] We use the language of Eric M. Leeper (1991), where active monetary policy means a strong response of interest rates to inflation while passive fiscal policy means a strong response of taxes to debt outstanding and vice-versa. We make the definitions precise in the context of our model below.

stickiness is modelled using the Calvo formulation. The constant probability of not adjusting prices is given by α, with prices that do not adjust partially indexed to past inflation, with the extent of indexation given by γ.

The government is subject to a flow budget constraint and conducts monetary and fiscal policies using endogenous feedback rules. For simplicity, we assume that the government issues only one-period nominal debt, levies lump-sum taxes, and uses lump-sum transfers.[2] The government spending-to-output ratio g_t and transfer payments-to-output ratio s_t follow exogenous processes. Government spending is completely wasteful. The government controls the one-period nominal interest rate R_t.

Monetary policy is modelled using an interest rate rule that features interest rate smoothing and a systematic response of the nominal interest rate to the deviation of inflation π_t from a time-varying target π_t^* and the deviation of output Y_t from the natural level of output Y_t^*.[3] The extent of interest rate smoothing is given by ρ_R and the feedback parameters on inflation deviation and output deviation by ϕ_π and ϕ_Y respectively. Monetary policy shock, the non-systematic component in the rule, is given by $\varepsilon_{R,t}$.

Fiscal policy is modelled using a tax rule that features tax smoothing and a systematic response of the tax revenues-to-output ratio τ_t to the deviation of outstanding government debt-to-output ratio b_{t-1} from a time-varying target b_{t-1}^*, the deviation of output from the natural level of output, and the deviation of government spending-to-output ratio from its steady state level. The extent of tax smoothing is given by ρ_τ and the feedback parameters on inflation deviation, output deviation, and government spending deviation by ψ_b, ψ_Y, and ψ_g respectively. Fiscal policy shock, the non-systematic component in the rule, is given by $\varepsilon_{\tau,t}$.

The economy is driven by the nine aggregate shocks δ_t, A_t, θ_t, g_t, s_t, π_t^*, b_t^*, $\varepsilon_{R,t}$, and $\varepsilon_{\tau,t}$. The growth rate of the technology shock $a_t \equiv A_t/A_{t-1}$ follows an AR(1) process in logs, as do δ_t, θ_t, and π_t^*. Three other shocks g_t, s_t, and b_t^* follow an AR(1) process in levels. All these processes have mean zero Gaussian innovations. The policy shocks $\varepsilon_{R,t}$ and $\varepsilon_{\tau,t}$ follow an i.i.d. mean zero Gaussian process.

We first solve the problem of households and firms given the monetary and fiscal policy rules and derive the equilibrium conditions. We then use approximation methods to solve the model: we detrend variables on the balanced growth path by normalizing by A_t and obtain a first-order approximation to the equilibrium conditions around the non-stochastic steady state.[4] The linearized equations are standard and are provided in the web appendix. Here we describe the policy rules and the government budget constraint to facilitate our discussion of policy regimes:

$$\begin{aligned}\hat{R}_t &= \rho_R \hat{R}_{t-1} + (1-\rho_R)\,\phi_\pi\left(\hat{\pi}_t - \hat{\pi}_t^*\right) \\ &\quad + (1-\rho_R)\,\phi_Y\left(\widehat{\tilde{Y}}_t - \widehat{\tilde{Y}}_t^*\right) + \varepsilon_{R,t},\end{aligned}$$

$$\begin{aligned}\hat{\tau}_t &= \rho_\tau \hat{\tau}_{t-1} + \left(1-\rho_\tau\right)\psi_b\left(\hat{b}_{t-1} - \hat{b}_{t-1}^*\right) \\ &\quad + \left(1-\rho_\tau\right)\psi_Y\left(\widehat{\tilde{Y}}_t - \widehat{\tilde{Y}}_t^*\right) \\ &\quad + \left(1-\rho_\tau\right)\psi_g \hat{g}_t + \varepsilon_{\tau,t},\end{aligned}$$

$$\begin{aligned}\hat{b}_t &= \frac{1}{\beta}\hat{b}_{t-1} + \frac{\bar{b}}{\beta}\left(\hat{R}_{t-1} - \hat{\pi}_t - \Delta\widehat{\tilde{Y}}_t - \hat{a}_t\right) \\ &\quad + \hat{g}_t - \hat{\tau}_t + \hat{s}_t.\end{aligned}$$

The equilibrium of the economy will be determinate either if monetary policy is active while fiscal policy is passive (the AMPF regime) or if monetary policy is passive while fiscal policy is active (the PMAF regime). Multiple equilibria exist if both monetary and fiscal policies are passive (the PMPF regime). In our model, monetary policy is active if $\phi_\pi > 1 - \phi_Y\left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$, where $\tilde{\beta} = \frac{\gamma+\beta}{1+\gamma\beta}$ and $\tilde{\kappa} = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\varphi\theta)(1+\gamma\beta)}(1+\varphi)$, and fiscal policy is active if $\psi_b < \frac{1}{\beta} - 1$.

[2] It will be interesting to relax the restriction of one-period governemnt bond by allowing for long term debt as in John H. Cochrane (2001). This will reduce inflation volatility under an active fiscal regime.

[3] Natural level of output is defined as the ouptut that would prevail under flexible prices and in the absence of shocks to the elasticity of substitution among differentiated goods.

[4] We denote variable $\frac{X_t}{A_t}$ by $\tilde{X}_t$. We define the log deviations of a variable X_t from its steady state $\bar{X}$ as $\hat{X}_t = \ln X_t - \ln \bar{X}$, except for four fiscal variables: $b_t = b_t - \bar{b}$, $\hat{g}_t = g_t - \bar{g}$, $\hat{\tau}_t = \tau_t - \bar{\tau}$, and $\hat{s}_t = s_t - \bar{s}$.

II. Estimation

A. Method

The system of linearized equations is solved for its state space representation. The solution method for linear rational expectations models of Christopher A. Sims (2002) is applied under determinacy. Under indeterminacy, we employ a generalization of this method proposed in Lubik and Schorfheide (2004) which expresses the solution of the model as

$$\mathbf{z}_t = \Gamma_1^* \mathbf{z}_{t-1} + (\Gamma_{0,\varepsilon}^* + \Gamma_{0,\zeta}^* M)\boldsymbol{\varepsilon}_t + \Gamma_{0,\zeta}^* \boldsymbol{\zeta}_t, \tag{1}$$

where $\mathbf{z}_t$ is a vector of model variables, $\boldsymbol{\varepsilon}_t$ is a vector of fundamental shocks, and $\boldsymbol{\zeta}_t$ is a vector of sunspot shocks. The coefficient matrices Γ_1^*, $\Gamma_{0,\varepsilon}^*$, and $\Gamma_{0,\zeta}^*$ are a function of the structural model parameters, where $\Gamma_{0,\zeta}^* = 0$ under determinacy. Indeterminacy introduces additional parameters, given by the matrix M in (1). With a distributional assumption on $\boldsymbol{\zeta}_t$, one can construct the likelihood of the solution of the model using the Kalman filter. We use conventional Bayesian methods widely used in the DSGE literature to fit the model to the data.[5]

B. Results

Data

We use six key quarterly U.S. data as observables: per-capita output growth, annualized inflation, annualized federal funds rate, tax revenues-to-output ratio, market value of government debt-to-output ratio, and government spending-to-output ratio.[6] As in Lubik and Schorfheide (2004), we estimate the model over two samples: a pre-Volcker (1960:$Q$1-1979:$Q$2) sample and a post-Volcker (1982:$Q$4 - 2008:$Q$2) sample. In particular, we drop the Volcker disinflation period.

Priors

We calibrate $\varphi = 1$ and the steady state value of the elasticity of substitution $\theta = 8$.[7] We calibrate ρ_{π^*} and ρ_{b^*} to 0.995 to restrict the role of time-varying policy targets to explaining low frequency behavior of the data only. For the rest of the parameters which are all estimated, most of the priors that we use are standard in the literature.[8] We discuss in detail two sets of priors that are unique to our analysis.

The first are those related to the policy rules. We impose each policy regime by reparameterizing two key policy parameters in the monetary and fiscal rules: ϕ_π and ψ_b. Denote the boundaries for active and passive policies by $\Phi^M(\boldsymbol{\theta}) \equiv 1 - \phi_Y\left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$ and $\Phi^F(\boldsymbol{\theta}) \equiv \frac{1}{\beta} - 1$ respectively. Then let

$$\begin{aligned}
\phi_\pi &= \Phi^M(\boldsymbol{\theta}) + \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) + \psi_b^*, \\
\phi_\pi &= \Phi^M(\boldsymbol{\theta}) - \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) - \psi_b^*, \\
\phi_\pi &= \Phi^M(\boldsymbol{\theta}) - \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) + \psi_b^*,
\end{aligned}$$

for the AMPF, PMAF, and PMPF regimes respectively.

The newly introduced parameters, ϕ_π^* and ψ_b^*, are assumed positive by specifying a gamma prior distribution with means 0.5 and 0.05 and standard deviations 0.2 and 0.04, respectively. This reparametarization thus ensures that we completely impose a particular policy regime during estimation. The implied 90 percent prior probability interval for ϕ_π is $(1.189 - 1.811)$ under AM and $(0.185 - 0.811)$ under PM while for ψ_b it is $(0.003 - 0.107)$ under PF and $(-0.102 - 0.003)$ under AF.[9]

The second are those related to the case of indeterminacy. The results we report are based on setting the prior mean of M to zero. Since $\Gamma_{0,\varepsilon}^*$ and $\Gamma_{0,\zeta}^*$ in (1) are orthogonal, this specification implies that the initial impact of fundamental shocks is orthogonal to that of sunspot shocks at the prior mean.[10]

[5] For details, please see the web appendix.

[6] For details on the data, please see the web appendix.

[7] θ and φ are not seperately identified from α.

[8] Except for the mean value of observables and the technology growth rate, we use the same priors across the two sample periods.

[9] These intervals cover the range of values found in the literature, for example, Troy A. Davig and Eric M. Leeper (2011).

[10] We tried two other specifications and our results are robust to these variations. First, as in Lubik and Schorfheide (2004) we set the prior mean of M so that the impact impulse responses of endogenous variables to fundamental shocks are as close as possible across the boundary between the determinacy and indeterminacy region. Second, we use a quite diffuse prior for M.

MODEL COMPARISON

We use marginal likelihoods across different policy regime specifications to compare model fit. As Table 1 shows, the data favors the PMPF regime pre-Volcker, which implies indeterminacy, and the AMPF regime post-Volcker.[11] While in this regard, our finding is in line with Lubik and Schorfheide (2004), we will show below that the propagation mechanism under our PMPF regime is substantively different from that under indeterminacy in their paper.

POSTERIOR ESTIMATES

Most of our posterior estimates are in line with the literature. Here we discuss the estimates of the key policy parameters. The implied estimate of the posterior mean for ϕ_π is 0.188 pre-Volcker and 1.299 post-Volcker while for ψ_b it is 0.094 pre-Volcker and 0.091 post-Volcker. The 90 percent posterior probability intervals for ϕ_π and ψ_b are $(0 - 0.354)$ and $(0.040 - 0.146)$ pre-Volcker and $(0.922 - 1.680)$ and $(0.0240 - 0.168)$ post-Volcker.[12]

PROPAGATION OF SHOCKS

In Figs.$1-2$ we present impulse responses to monetary and fiscal policy shocks for the best fitting models: PMPF pre-Volcker and AMPF post-Volcker. The effects of monetary and fiscal policy shifts on the aggregate economy are substantially different across the two time-periods. In particular, the monetary and fiscal policy transmission mechanisms in our estimated PMPF model pre-Volcker are similar to those under PMAF in many important dimensions.

Pre-Volcker, as shown in Fig.1, a monetary contraction (i.e. an unanticipated increase in the nominal interest rate) led to an increase, not a decrease, in inflation. This was in turn accompanied by a decline in the debt-to-output ratio. Thus increased pressures on government debt due to increases in interest payments following a monetary contraction were stabilized (partly) through a higher inflation rate. This result is in line with the prediction of the FTPL. While the pre-Volcker U.S. economy was characterized by PMPF, it was under the AMPF regime post-Volcker. Accordingly, the impulse responses to a monetary shock are in line with standard models of price determination: Fig.1 shows that a monetary contraction led to a decrease, not an increase, in inflation.

Moreover, pre-Volcker, the impulse responses to various fiscal shocks also resemble those predicted by the FTPL. For example, an exogenous increase in the tax-to-output ratio produces a recession, decreasing output and inflation as shown in Fig.2, an event one would not observe under conventional AMPF. The interest rate decreases as well, only weakly responding to lower inflation due to passive monetary policy. In contrast, post-Volcker, as Fig.2 makes clear, exogenous changes in tax revenues did not affect output, inflation, and the interest rate, a conventional "Ricardian" equivalence result.

We emphasize that our results for pre-Volcker are data-driven, not hard-wired into our model specification. We find that under PMPF the model has the flexibility to produce a wide range of dynamics, including those that would prevail under PMAF or AMPF or neither. The model under PMPF has this flexibility mainly because indeterminacy introduces an additional channel for the propagation of fundamental shocks, $\Gamma^*_{0,\zeta} M$ in (1), which reflects agent's beliefs. By characterizing the full set of indeterminate beliefs with the additional parameters in M and the sunspot shocks, we construct the distribution of the agent's beliefs conditional on the data. In doing so, we find that the pre-Volcker data favors the agent's belief that inflation would increase on impact (and afterwards) in response to monetary contractions and that inflation would play a significant role in stabilizing government debt. Under PMPF post-Volcker however, our

[11] Note that if we had restricted the estimation to determinacy, then PMAF fits the data better than AMPF pre-Volcker. This result is in contrast with that of Traum and Yang (2011), who use a different model and data. In future, it will be interesting to fully explore the main reasons for this difference.

[12] Note that our posterior estimate of the monetary policy reaction parameter ϕ_π in the PMPF regime pre-Volcker is much smaller than the estimates in the literature. There are two main reasons for this result. First, the prior distribution for ϕ_π implied by the prior distribution for ϕ_π^* has most of the probability mass away from the boundary condition for active and passive monetary policy, while the literature assumes the prior distribution is skewed towards the boundary condition. Second, inflation stabilization is partly achieved through the government budget constraint and hence monetary policy is estimated to have played a less significant role for stabilizing inflation.

TABLE 1—COMPARISON OF LOG LIKELIHOODS OF ALTERNATE REGIMES

	Determinacy		Indeterminacy
	AMPF	PMAF	PMPF
Pre-Volcker	-542.0	-539.8	-522.1
Post-Volcker	-554.4	-564.5	-569.8

Note: Table reports log marginal likelihoods that are computed using the harmonic mean estimator.

estimates imply that the public did not believe inflation to be important in debt stabilization.

III. Conclusion

Our exercise suggests that some of the conventional wisdoms in macroeconomics may critically depend on seemingly innocuous assumptions, such as passive fiscal policy and equilibrium determinacy, as well as the widespread practice of excluding fiscal variables in empirical analysis. We show that these assumptions matter for the transmission mechanism of monetary and fiscal policy. Indeed, much work remains to be done to assess the full implications of specifying fiscal behavior carefully while estimating policy-oriented models.

In ongoing work, Saroj Bhattarai, Jae W. Lee, and Woong Y. Park (2011), we fully explore the implications of our results for classic questions in U.S. business cycles and also plan to assess their robustness. In particular, given Christopher A. Sims and Tao Zha (2006)'s findings that including a monetary aggregate in the central bank reaction function affects inference regarding indeterminacy pre-Volcker, it will be desirable to see if this alteration to the monetary policy rule influences our model comparison results. More generally, as a research agenda, it would be fruitful to extend our sub-sample analysis to estimate a DSGE model with recurring regime switching in both monetary and fiscal policies using the methodology in Roger E. A. Farmer, Daniel F. Waggoner, and Tao Zha (2011).

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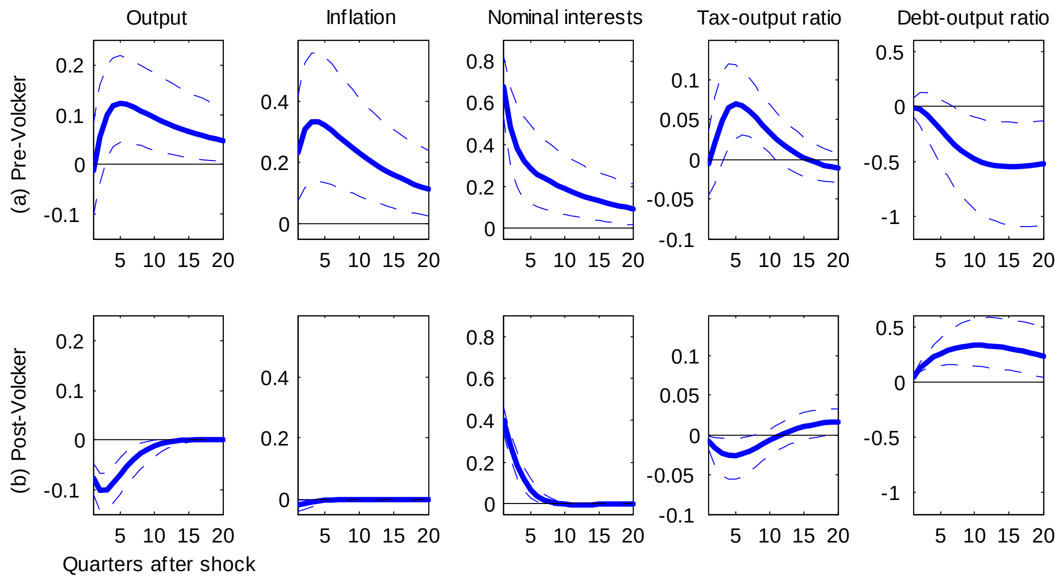

FIGURE 1. IMPULSE RESPONSES TO A MONETARY POLICY SHOCK

Note: Figure plots pointwise posterior means (solid lines) and 90-percent probability intervals (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{R,t}$. Row (a) presents results of the PMPF regime, pre-Volcker, and row (b) presents results of the AMPF regime, post-Volcker. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for the rest of the variables.

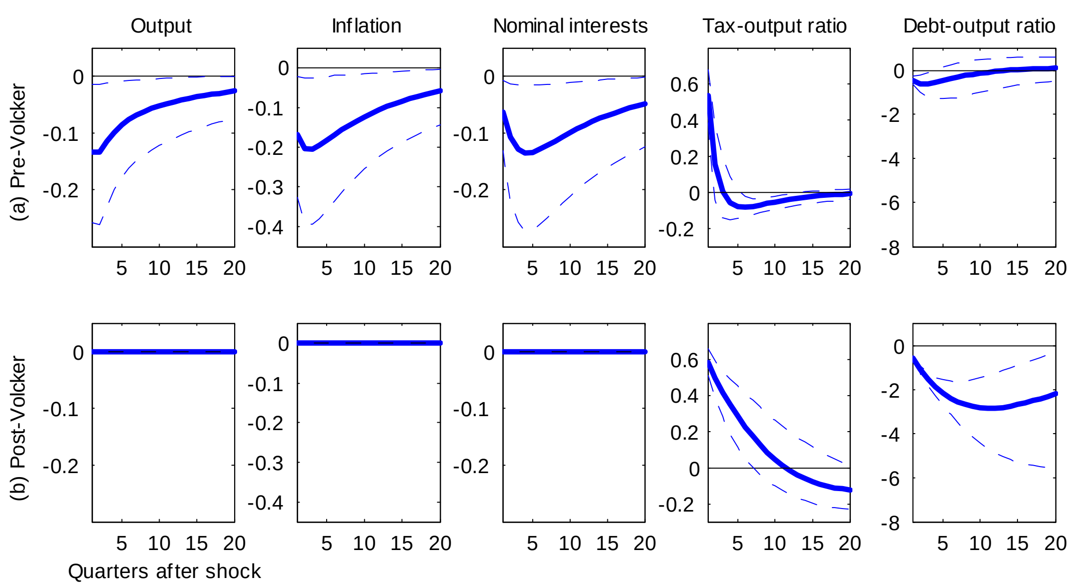

FIGURE 2. IMPULSE RESPONSES TO A FISCAL POLICY SHOCK

Note: Figure plots pointwise posterior means (solid lines) and 90-percent probability intervals (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{\tau,t}$. See the note in Figure 1.