# Monetary Policy, Expectations and Business Cycles in the U.S. Post-War Period*

Giovanni Nicolò, UCLA†

November 28, 2017

Job Market Paper

The most updated version of the paper can be found here.

**Abstract**

This paper examines the interactions between monetary policy and the formation of expectations to explain U.S. business cycle fluctuations in the post-war period. I estimate a conventional medium-scale New-Keynesian model, in which I relax the assumption that the central bank pursued an 'active' monetary policy — i.e. that stabilizes inflation and output growth — over this entire period. I find that between 1955 and 1979 monetary policy was 'passive', and structural shocks de-anchored inflation expectations from the central bank's long-run target. Fundamental productivity and cost shocks were the primary cause of volatility and propagated via persistent self-fulfilling inflationary expectations. By contrast, non-fundamental 'sunspot' shocks, caused by unexpected changes in inflation expectations, were insignificant sources of uncertainty.
JEL: C11, C52, C54, E31, E32, E52.

*I am grateful to Roger E.A. Farmer, Francesco Bianchi, Aaron Tornell and Vincenzo Quadrini for invaluable support and advice. I also thank Andrea Ajello, Andy Atkeson, Saki Bigio, Martin Bodenstein, Matteo Crosignani, Pablo A. Cuba-Borda, Pablo Fajgelbaum, Francesco Ferrante, Etienne Gagnon, Ana Galvao, Francois Geerolf, Michela Giorcelli, Christopher J. Gust, Jinyong Hahn, Edward P. Herbst, Matteo Iacoviello, Cosmin Ilut, Benjamin K. Johannsen, Robert J. Kurtzman, Lee E. Ohanian, Anna Orlik, Matthias O. Paustian, Andrea Prestipino, Andrea Raffo, John Rogers, Robert J. Tetlow, Pierre-Olivier Weill, Fabian Winkler, seminar participants at UCLA, the Monetary Affairs Workshop of the Federal Reserve Board, and conference participants at the Applications of Behavioral Economics and Multiple Equilibrium Models to Macroeconomic Policy Conference and the Asian Meeting of the Econometric Society for valuable comments.

†Department of Economics, University of California, Los Angeles. Address: 8292, Bunche Hall, Los Angeles, CA 90095, U.S.A. Email: gnicolo@ucla.edu.

# 1 Introduction

This paper examines the interactions between monetary policy and the formation of expectations to explain U.S. business cycle fluctuations in the post-war period. Previous studies mainly use medium-scale New-Keynesian (NK) models and assume that the central bank implemented an 'active' monetary policy that systematically stabilizes inflation and output growth during the entire post-war period.

This assumption does not reconcile with the data. From the late 1950s through the 1970s, the U.S. economy experienced high volatility, and inflation was high and rising. Assuming an 'active' monetary policy does not allow to account for propagation mechanisms based on the de-anchoring of inflationary expectations in response to structural shocks. However, it simplifies the construction of the solution in such models.

I estimate the conventional medium-scale NK model by Smets and Wouters (2007) (henceforth SW), in which I relax the key assumption that the central bank pursued an 'active' monetary policy both before and after 1979. If monetary policy is passive, the model is indeterminate and characterized by multiple equilibrium paths. Two features of the model become relevant to explain the persistence and volatility of the data. First, the propagation of structural shocks depends on self-fulfilling expectations that generate an additional source of persistence. Second, unexpected changes in expectations constitute non-fundamental 'sunspot' disturbances that generate an additional source of uncertainty.

I find four main results. First, the conduct of U.S. monetary policy changed in the post-war period. Monetary policy was passive between 1955 and 1979, while it pursued an active inflation targeting since 1984. Compared to previous studies that use medium-scale models, this result rejects the imposed assumption that monetary policy was active before 1979.

Second, the evidence of a passive monetary policy from 1955 to 1979 substantially affects the explanation of U.S. business cycles over this period. According to the estimated model, fundamental productivity and cost shocks were the primary drivers of the run-up in the inflation rate from the early 1960s to 1979. Positive technology shocks in the 1960s de-anchored inflation expectations from the central bank's long-run target and generated persistent *inflationary* pressures via self-fulfilling expectations.[1] Mark-up shocks account for the sudden inflationary episodes related to the oil crisis during the 1970s, while they are not significant drivers of the rise in inflation during the 1960s.

Third, the high volatility of inflation and output growth before 1979 was caused by fundamental disturbances and not by sunspot shocks. In a passive monetary policy regime,

[1]This result is supported by the empirical evidence documented by Fernald (2014a) and Gordon (2000) among others, who argue that the U.S. economy experienced a period of exceptional growth in productivity since World War II until the early 1970s.

non-fundamental shocks potentially lead to additional macroeconomic instability. By contrast, the estimation of the SW model shows that non-fundamental sunspot shocks were not significant drivers of volatility between 1955 and 1979.

Finally, I revisit the question on the sources of the reduction in U.S. macroeconomic volatility from the 1980s to 2007. I investigate whether the observed decrease in volatility is explained by a more active monetary policy since the early 1980s, as opposed to smaller structural shocks. Based on the SW model, I find that the reduction in macroeconomic uncertainty was a combination of both a change in monetary policy to a more active stance *and* a lower volatility of the shocks.

To solve the medium-scale model of SW with a passive monetary policy, I use the methodology developed in Bianchi and Nicolò (2017), which simplifies technical complexities that hamper the implementation of existing solution methods to medium-scale models (Lubik and Schorfheide, 2003, Farmer et al., 2015).

To the best of my knowledge, this paper is the first study that quantitatively investigates the role of self-fulfilling expectations and non-fundamental disturbances for U.S. macroeconomic instability prior to 1979 in the context of a medium-scale model. Previous studies that allow for indeterminacy of U.S. monetary policy mainly adopt small-scale NK models and rationalize the empirical properties of the data before 1979 with a passive monetary policy (Clarida et al., 2000, Lubik and Schorfheide, 2004).

The adoption of a medium-scale model provides two advantages. First, a richer *dynamic* and *stochastic* structure could explain the macroeconomic volatility and inflation persistence before 1979, even when monetary policy is *active*. This explanation could overturn the results in previous studies that adopted small-scale models (Beyer and Farmer, 2007a). Second, the richer structure constitutes a suitable framework to study the quantitative implications for business cycle fluctuations.

The rest of the paper is organized as follows. Section 2 highlights the contributions of the paper to the related literature. Section 3 motivates the adoption of medium-scale models to properly assess the role of U.S. monetary policy to explain business cycles. Section 4 describes the main features of the SW model and the data used to conduct the estimation of the model using Bayesian techniques. Section 5 explains the methodology developed in Bianchi and Nicolò (2017) and its implementation to construct and estimate the SW model allowing for indeterminacy. Section 6 presents the findings. Section 7 concludes.

## 2 Related Literature

The paper contributes to five strands of the literature. First, it provides an interpretation of U.S. business cycle fluctuations in the United States based on the role of self-fulfilling expectations. Previous studies mainly abstract from the possibility of observing policies that lead to indeterminate outcomes (Bianchi, 2013, Fernandez-Villaverde et al., 2010, Del Negro and Eusepi, 2011, Bianchi and Ilut, 2017). The contribution of this paper is to quantify the implications of a passive monetary policy for U.S. business cycle fluctuations in the post-war period. Under such regime, the propagation of structural shocks is more persistent due to the formation of self-fulfilling expectations. This mechanism identifies different determinants of business cycles. The upward trend in the inflation rate observed since the early 1960s is due to persistent technology shocks that generated strong economic activity and self-fulfilling inflationary expectations. Moreover, I show that sunspot shocks play no quantitative role in explaining the volatility observed before 1979.

Second, a vast literature rationalizes the role of monetary policy for the behavior of the data in the post-war period using univariate or small-scale Linear Rational Expectations (LRE) models (Clarida et al., 2000, Lubik and Schorfheide, 2004, Coibon and Gorodnichenko, 2011, Boivin and Giannoni, 2006, Yasuo Hirose and Zandweghe, 2017, Bhattarai et al., 2016). Their findings align and support the evidence that the monetary authority failed to implement an active inflationary targeting before 1979.[2] However, a richer dynamic and stochastic structure could suffice to explain the macroeconomic volatility and inflation persistence before 1979, even when monetary policy is *active* (Beyer and Farmer, 2007a).[3] This paper addresses this concern using a canonical medium-scale NK model and shows that earlier findings carry over to the SW model.

Third, the adoption of a medium-scale LRE model raises two technical complexities. First, the partition of the parameter space into a determinate and indeterminate region is unknown for richer models. Second, the construction of the indeterminate solution requires a substantial amount of coding using the existing solution methods (Lubik and Schorfheide, 2003, Farmer et al., 2015). Given the technical complexities, a researcher commonly estimates a medium-scale model by restricting *a priori* the parameter space to the unique, determinate region (Smets and Wouters, 2007, Arias et al., 2017). In this paper, I implement the method-

[2]Alternative explanations for the run-up of U.S. inflation since the early 1960s relate to the possibility that policymakers overestimated potential output (Orphanides, 2002) and the persistence of inflation in the Phillips curve (Primiceri, 2006). In this paper, I focus on understanding the mechanisms through which the de-anchoring of inflation expectations due to structural shocks could have played a relevant role to explain the macroeconomic instability in the period prior to 1979.

[3]A closely related literature also discusses the concerns due to model misspecification for the empirical performance of Dynamic Stochastic General Equilibrium models and provides policy analysis approaches to deal with it (Del Negro et al., 2007, Del Negro and Schorfheide, 2009).

ology we developed in Bianchi and Nicolò (2017) to relax this assumption and estimate the medium-scale model by SW over the *entire* parameter space. I find that the assumption imposed in SW is rejected for the period before 1979. Importantly, I show that the assumption has quantitative implications for the identification of the main drivers of U.S. business cycles.

Fourth, the paper contributes to the literature that studies the sources of the reduction in U.S. macroeconomic volatility from the 1980s to 2007. I investigate the validity of two prominent theories that have been advocated to explain this empirical phenomenon. First, several studies show that the behavior of the data changed due to a decrease in the variance of the shocks driving the economy in the period subsequent the Volcker disinflation (Sims and Zha, 2006, Primiceri, 2005, Justiniano and Primiceri, 2008, Alejandro Justiniano and Tambalotti, 2010, Alejandro Justiniano and Tambalotti, 2011). This strand of the literature considers that the reduction in volatility is not related to monetary policy and it can therefore be considered as "good luck". Second, the work of Clarida et al. (2000) and Lubik and Schorfheide (2004) among others indicates that monetary policy acted more systematically since the 1980s, therefore suggesting a view related to the "good policy". In this paper, I find that the data supports both theories. Both a change in the conduct of monetary policy to a more active stance *and* a significant drop in the volatility of structural shocks account for the decrease in U.S. macroeconomic uncertainty.

Finally, the paper contributes to the literature that studies the empirical implications of dynamic indeterminacy.[4] The contributions of Farmer and Guo (1994) and Farmer and Guo (1995) focus on relevance of sunspot shocks to explain business cycle fluctuations. More recently, Lubik and Schorfheide (2004) empirically evaluate the possibility that monetary policy could lead to indeterminate outcomes and Bhattarai et al. (2016) enrich this analysis by accounting for a non-trivial interaction between monetary and fiscal policy. This paper considers the richer dynamic and stochastic structure of the SW model to empirically study the implications of dynamic indeterminacy for U.S. business cycles in the post-war period.

## 3 Reasons for the Adoption of Medium-scale Models

Several studies focus on the conduct of U.S.monetary policy in the post-war period by adopting univariate and small-scale models. Clarida et al. (2000) estimate a monetary policy reaction function and therefore address the question using a univariate structural model.

[4]A second generation of models in the literature about indeterminacy relates to the possibility of observing multiple steady states for a given model. In this paper, I will refer to indeterminacy only as the dynamic properties of the model in the neighborhood of the unique steady state of a model.

Lubik and Schorfheide (2004) (henceforth LS) test for indeterminacy in U.S. monetary policy during the post-war period by considering a conventional three-equation NK model.

However, two advantages arise with the adoption of richer models. Section 3.1 discusses an identification problem that could potentially undermine and overturn the results obtained with parsimonious models. Section 3.2 provides insights on how the conduct of a passive monetary policy affects the propagation of fundamental shocks via the formation of self-fulfilling expectations and allows for non-fundamental sunspot shocks to affect the economy. In this paper, the adoption of the medium-scale model in SW allows to verify whether the results in earlier studies are susceptible to the modeling choice and to assess the quantitative implications of a passive monetary policy for U.S. business cycles.

## 3.1 Identification Problem

Previous studies that allow for indeterminacy in U.S. monetary policy mainly adopt small-scale NK models and rationalize the empirical properties of the data before 1979 with a passive monetary policy (Clarida et al., 2000, Lubik and Schorfheide, 2004). If monetary policy is 'passive', two features of the model become relevant to explain the persistence in inflation dynamics and the high volatility of U.S. macroeconomic data over this period. First, the propagation of structural shocks depends on self-fulfilling expectations that generate an additional source of persistence. Second, unexpected changes in expectations constitute non-fundamental 'sunspot' disturbances that generate an additional source of uncertainty.

However, findings in earlier studies are potentially susceptible to the choice of parsimonious models (Beyer and Farmer, 2007a). Small-scale models impose restrictions on the structure of the underlying economy. By excluding richer models, the restrictions favor the result of a passive monetary policy since missing propagation mechanisms are misinterpreted as evidence of this conclusion. The identification problem relates to the possibility that a model with a richer *dynamic* and *stochastic* structure could explain the macroeconomic volatility and inflation persistence before 1979, even when monetary policy is *active*. Adopting the medium-scale NK model of SW allows to verify whether previous findings carry over to a richer structure.[5]

[5]LS acknowledge that their results are sensitive to model misspecification since missing propagation mechanisms would favor the result of model indeterminacy. Their robustness check consists in comparing the fit of a small-scale NK model for the Pre-Volcker period with a richer model to account for missing propagation mechanisms. However, the comparison is between two structurally different models and the robustness check could therefore be sensitive to the choice of which propagation mechanism are included in the richer model. In this paper, I am instead considering the SW model for both the determinate and the indeterminate regions, while aiming at reducing the identification problem that is inherent to the question by considering a medium-scale model.

In the spirit of Beyer and Farmer (2007a), the following analytic example provides an intuition of the identification problem that an econometrician faces when testing for indeterminacy. Suppose that a researcher studies the dynamics of the inflation rate using two alternative univariate LRE models. One model explains current inflation only as a function of expected inflation as described by equation (1)

$$\pi_t = aE_t(\pi_{t+1}). \tag{1}$$

Since the endogenous variable is expectational, the model is well-specified when the associated one-step ahead forecast error is also defined

$$\eta_t \equiv \pi_t - E_{t-1}(\pi_t). \tag{2}$$

Considering the case of $|a| > 1$, the model is *indeterminate*, and any process for inflation and its expectation that takes the following form solves the univariate model in (1) and (2)

$$\begin{cases} \pi_t & = & \lambda\pi_{t-1} + \eta_t, \\ E_t\left(\pi_{t+1}\right) & = & \lambda^2\pi_{t-1} + \lambda\eta_t, \end{cases} \tag{3}$$

where $\lambda \equiv a^{-1} < 1$. According to this model, the dynamics are explained by lagged inflation rate, and the only source of volatility is the non-fundamental shock, $\eta_t$.

The alternative univariate LRE model considered by the econometrician describes current inflation as a function not only of expected inflation but also of lagged inflation and a fundamental shock, $\varepsilon_t$,

$$\pi_t = aE_t(\pi_{t+1}) + b\pi_{t-1} + \varepsilon_t. \tag{4}$$

Given the definition of the forecast error $\eta_t \equiv \pi_t - E_{t-1}(\pi_t)$, the dynamics of the model depend on the two roots of the model denoted by $\theta$ and $\lambda$.[6] When only one root is unstable, the model has a unique, *determinate* solution. By assuming without loss of generality that $|\theta| > 1$ and $|\lambda| < 1$, the solution of the determinate model is

$$\begin{cases} \pi_t & = & \lambda\pi_{t-1} + \frac{(\lambda+\theta)}{\theta}\varepsilon_t, \\ E_t\left(\pi_{t+1}\right) & = & \lambda^2\pi_{t-1} + \lambda\frac{(\lambda+\theta)}{\theta}\varepsilon_t. \end{cases} \tag{5}$$

The identification problem arises due to the observational equivalence of the two alternative

[6] It can be shown that the roots of the model are related to the structural parameters of the model as follows: $a = 1/(\lambda + \theta)$ and $b = \lambda\theta/(\lambda + \theta)$.

models. Without further information about the true variance of the shocks $\eta_t$ and $\varepsilon_t$, the *indeterminate* model in (3) and the *determinate* model in (5) are characterized by the same likelihood function.

However, the choice of a parsimonious structure affects the inference of the econometrician by erroneously favoring the indeterminate model in (3). Suppose that the true data generating process for the inflation rate is the richer, determinate model in (4). Also, suppose the researcher chooses a parsimonious dynamic structure such as in (1) where lagged inflation is omitted. The inference would therefore mistakenly lead the econometrician to conclude that the data is consistent with the dynamics of the indeterminate model in (3) due to the observational equivalence.

The identification problem suggests that the findings in earlier studies of a passive monetary policy before 1979 could be undermined by the choice of a parsimonious small-scale model. Abstracting from relevant propagation mechanisms and structural shocks would favor this result. The adoption of richer models allows to verify if earlier findings rely on the modeling choice.

In this paper, I consider the medium-scale model of SW to verify whether the findings of Clarida et al. (2000) and LS carry over to a model with a richer dynamic structure. As presented in Section 6.1.1, I find that the data still supports the evidence of a passive monetary policy before 1979. I then argue in Section 6.2 and 6.3 that the distinctive propagation of structural shocks under such monetary policy regime is the feature of the indeterminate representation that the data favors. Finally, in Section 6.1.3, I also shed light on the debate of whether the Fed did not follow an active inflation targeting during the period after the 2001 slump and therefore generated economic conditions that led to the Great Recession. Importantly, I show that while the analysis conducted using a small-scale model suggests the latter interpretation of the events, using the SW model the data indicates that the monetary authority implemented an active policy.

## 3.2 Digging into the Mechanisms

The second advantage of adopting a medium-scale model such as SW is to provide a suitable framework to quantitatively assess the implications that a passive monetary policy has on the macroeconomy. In this section, I use a simple classical monetary model to show that if monetary policy is passive, the dynamic and stochastic properties of the model differ in two dimensions. First, the propagation of fundamental shocks through the economy differs due to the formation of self-fulfilling expectations in response to the shocks. Second, the model is subject to an non-fundamental sunspot disturbances. While small-scale models are not sufficiently detailed, medium-scale models account for richer transmission mechanisms and provide a quantitative assessment of the relative importance in the data.

To provide the intuition, I consider a classical monetary model described by the Fisher equation

$$R_t = r_t + E_t(\pi_{t+1}), \tag{6}$$

and the simple Taylor rule

$$R_t = \phi_\pi \pi_t, \tag{7}$$

where $R_t$ and $\pi_t$ denote the deviations of the nominal interest rate and the inflation rate from their target level. I assume that the real interest rate $r_t$ is given and follows a mean-zero Gaussian i.i.d. distribution.[7] To properly specify the model, I also define the one-step ahead forecast error associated with the expectational variable, $\pi_t$, as

$$\eta_t \equiv \pi_t - E_{t-1}(\pi_t). \tag{8}$$

Combining (6) and (7), I obtain the univariate model

$$E_t(\pi_{t+1}) = \phi_\pi \pi_t - r_t. \tag{9}$$

In this simple model, the monetary authority is active if it responds to changes in the inflation rate by more than one for one. By recalling the Taylor rule in (7), this condition can be equivalently expressed as $|\phi_\pi| > 1$. The solution in this region of the parameter space is said to be determinate, and it is obtained by solving forward equation (9) as follows,

$$\begin{aligned} \pi_t &= \frac{1}{\phi_\pi} E_t(\pi_{t+1}) + \frac{1}{\phi_\pi} r_t \\ &= \frac{1}{\phi_\pi} r_t, \end{aligned} \tag{10}$$

where the second equality is derived by recalling the assumptions on $r_t$. The strong response of the monetary authority ensures that inflation is pinned down as a function of the exogenous real interest $r_t$.

Consequently, $E_t(\pi_{t+1}) = 0$, so that the expectations that agents hold about the future inflation rate are constant at its steady-state. The determinate solution is therefore described by the following system,[8]

[7] In the classical monetary model, the real interest rate results from the equilibrium in labor and goods market and it depends on the technology shocks. I am considering an exogenous process for the technology shocks and therefore I take the process for the real interest rate as given.

[8] Also, note that this implies that $\eta_t = \pi_t - E_{t-1}(\pi_t) = \pi_t = \frac{1}{\phi_\pi} r_t$. Therefore, the non-fundamental shock

$$\begin{cases} \pi_t = \frac{1}{\phi_\pi} r_t, \\ E_t(\pi_{t+1}) = 0. \end{cases} \tag{11}$$

Conversely, a passive monetary policy, $|\phi_\pi| \leq 1$, significantly affects the dynamic and stochastic properties of the model. The solution is obtained by combining the definition of the forecast error, $\eta_t$, with the univariate model in (9) as

$$\begin{aligned} \pi_t &= E_{t-1}(\pi_t) + \eta_t \\ &= \phi_\pi \pi_{t-1} + \eta_t - r_{t-1}. \end{aligned}$$

Expectations about future inflation are therefore described as,

$$\begin{aligned} E_t(\pi_{t+1}) &= \phi_\pi \pi_t - r_t \\ &= \phi_\pi^2 \pi_{t-1} + \phi_\pi \eta_t - (r_t + \phi_\pi r_{t-1}). \end{aligned}$$

Therefore, the solution corresponds to the following system of equations

$$\begin{cases} \pi_t = \phi_\pi \pi_{t-1} + \eta_t - r_{t-1}, \\ E_t(\pi_{t+1}) = \phi_\pi^2 \pi_{t-1} + \phi_\pi \eta_t - (r_t + \phi_\pi r_{t-1}). \end{cases} \tag{12}$$

The comparison of the representations in (11) and (12) shows that a change in monetary policy substantially affects the properties of the model and the interpretation of business cycle fluctuations in at least two dimensions. First, the impact and transmission of the *same* structural shock, $r_t$, on the dynamics of the model differs between the two specifications. While under determinacy the inflation rate also follows an i.i.d. process, under indeterminacy the shock de-anchors agents' expectations from the central bank's long-run target and transmits via the formation of self-fulfilling inflation expectations.[9] This is clearly not the case for the determinate solution where expectations are constant at the long-run inflation

$\eta_t$ is endogenously determined as a function of the structural shock, $r_t$.

[9] The inflation rate is not affected by the structural shock to the real interest rate whenever it is assumed that the real interest rate and the non-fundamental shock, $\eta_t$, are assumed to be uncorrelated. In a more general setting, the data could prefer a specification in which the correlation between structural shocks and non-fundamental shocks differs from zero.

rate and play no role for the dynamics of the model.

Second, if monetary authority is passive, the economy is subject to an additional, non-fundamental disturbance related to unexpected changes in agents' expectations, $\eta_t$. The sunspot shock therefore provides an additional source of uncertainty which could potentially help the model in matching the high volatility of the data in the period prior to the appointment of Paul Volcker as the chairman of the Federal Reserve System. By solving and estimating the SW model using the methodology in Bianchi and Nicolò (2017), I assess the quantitative relevance of each of these two properties of the model, especially for the period before 1979 that previous work showed to be associated with a passive monetary policy. In Section 6.2 and 6.3, I argue that the feature that the data favors is the distinctive propagation mechanism that relies on the formation of self-fulfilling expectations, while sunspot shocks were not significant sources of uncertainty.

# 4 The Model and Data

Dynamic stochastic general equilibrium (DSGE) models are useful tools to conduct quantitative policy analysis. To this purpose, a branch of the literature focused on developing richer models that could provide a better match with the data. Based on the conventional three-equation NK model, the work by Smets and Wouters (2003) and Christiano et al. (2005) expands the framework to account for relevant frictions and shocks. The model presented in Smets and Wouters (2007) now constitutes the heart of the structural DSGE models that are adopted by most central banks in advanced economies. While the reader is referred to the original paper for the details about the derivation of the model, this section describes its relevant features as well as the measurement equations and the data used to estimate the model using Bayesian techniques.

The model contains both real and nominal frictions. On the real side, households are assumed to form habit in consumption. By renting capital services to firms, households also face an adjustment cost and optimally choose the capital utilization rate with an increasing cost. Firms incur a fixed cost in production and are subject to nominal price rigidities *à la Calvo*, while indexing the optimized price to past inflation. Similarly, the model displays nominal wage frictions that also allow for indexation to past wage inflation.

The economy follows a deterministic, balanced growth path along which seven shocks drive the dynamics of the model. Three shocks affect the demand-side of the economy. A risk premium shock affects the household's intertemporal Euler equation by impacting the spread between the risk-free rate and the return on the risky asset. The investment-specific shock has an effect on the investment Euler equation that the household considers when choosing the amount of capital to accumulate. The third demand-side shock is an exogenous spending shock that impacts the aggregate resource constraint. Similarly, the supply-side of the economy is subject to three shocks: a productivity shocks well as price and wage mark-up shocks. Finally, the monetary authority follows a Taylor rule as described in equation (13),

$$R_t = \rho R_{t-1} + (1-\rho)\left\{r_\pi \pi_t + r_y\left(y_t - y_t^p\right) + r_{\Delta y}\left[\left(y_t - y_t^p\right) - \left(y_{t-1} - y_{t-1}^p\right)\right]\right\} + \varepsilon_t^R. \quad (13)$$

The monetary authority chooses the nominal interest rate, $R_t$, by allowing for some degree of interest rate inertia as measured by the parameter $\rho$. Changes in the inflation rate, $\pi_t$, and the output gap, defined as the deviations of actual output from its fully flexible price and wage counterpart, also generate a response by the monetary authority. The Taylor rule also accounts for changes in the output gap, while any unexpected deviation in the policy instrument is defined as a monetary policy shock, $\varepsilon_t^R$.[10]

To estimate the model, I use Bayesian techniques and the measurement equations that relate the macroeconomic data to the endogenous variables of the model are defined in equation (14),

$$\begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHours_t \\ dlP_t \\ FEDFUNDS_t \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{l} \\ \bar{\pi} \\ \bar{R} \end{bmatrix} + \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ i_t - i_{t-1} \\ w_t - w_{t-1} \\ l_t \\ \pi_t \\ R_t \end{bmatrix}, \quad (14)$$

where *dl* denotes the percentage change measured as log difference and *l* denotes the log. The observables are the seven macroeconomic quarterly U.S. macroeconomic time series used in SW, and they match the number of shocks that affect the economy. The series considered are: the growth rate in real GDP, consumption, investment and wages, log hours worked, inflation rate measured by the GDP deflator, and the federal funds rate.

The deterministic balanced growth path is defined in terms of four parameters: $\bar{\gamma}$, the quarterly trend growth rate common to real GDP, consumption, investment and wages; $\bar{l}$, the steady-state hours worked (normalized to zero); $\bar{\pi}$, the quarterly steady-state inflation rate; $\bar{R}$, the steady-state nominal interest rate. Hence, the measurement equations in (14) relate the macroeconomic time series with the corresponding endogenous variables of the model $\{y_t, c_t, i_t, w_t, l_t, \pi_t, R_t\}$, while accounting for a balanced growth path.

[10]The model also assumes that the monetary policy shock follows an autoregressive process defined by $\varepsilon_t^R = \rho_R \varepsilon_{t-1}^R + u_t^R$, where $u_t^R \overset{iid}{\sim} \mathcal{N}\left(0, \sigma_R^2\right)$. The same assumption also holds for the other structural shocks of the model.

While the full sample of SW ends in the fourth quarter of 2004, I updated the time series and in Section 6.1.1 I estimate the model over three sub samples. The first period starts in 1955:4, which corresponds to one year after the end of the Korean War, and it ends in 1969:4, the date in which the chairmanship of William Martin terminates.[11] The second sample considers the chairmanships of both Arthur Burns and William Miller, and it spans from 1970:1 until 1979:2. As I argue in Section 6.1.1, it is relevant to distinguish the first two sub samples since, in line with the evidence documented by Fernald (2014a) among others, the second period is characterized by slower productivity growth, thus resulting into a distinct balanced growth path. Finally, the beginning of the third period corresponds to 1984:1, in which Kim and Nelson (1999) initially identify a structural break in the U.S. business cycle. The end is marked by the Great Recession in 2007:3.

# 5 Methodology

The adoption of medium-scale DSGE models to study the conduct of monetary policy raises technical complexities. First, to compare determinate and indeterminate model solutions, a researcher must be able to partition the parameter space into a determinate and indeterminate region. While this partition can be easily derived analytically for small-scale models, it is generally unknown for larger models. Second, the model could be characterized by regions of the parameters space associated with multiple degrees of indeterminacy, and the researcher has to test for the potential degrees of indeterminacy of the model.[12] Third, standard software packages do not allow for indeterminacy.[13]

The application of existing solution methods to deal with indeterminacy in medium-scale models requires a substantial amount of coding work and technical skills (Lubik and Schorfheide, 2003, Lubik and Schorfheide, 2004). In practice, most of the papers simply rule out the possibility of indeterminacy by estimating the model exclusively in the determinate region of the parameter space. Among others, SW also adopt this approach and assume *a priori* a unique, determinate solution of the model.

The work of Bianchi and Nicolò (2017) develops a new method to solve and estimate LRE models allowing for indeterminacy of the model solution. While the paper builds on Lubik and Schorfheide (2003, 2004) and Farmer et al. (2015), the novelty is to provide an approach

[11] As argued in the work of Bernanke and Blinder (1992) and Bernanke and Mihov (1998), the federal funds rate has been the main policy tool in the United States in the post-war period, even if the Federal Reserve varied its operational procedures.

[12] A grid point method could be used to numerically identify the region of the parameter space associated with the indeterminate solution and the degrees of indeterminacy. However, this method does not provide a mapping between the dynamic properties of the model and its structural parameters.

[13] Examples of standard solution algorithm are the code developed by Sims (2001), Gensys, the toolkit by Uhlig (1999) and the algorithm of Anderson and Moore (1985) among others.

that, using the information in the data, endogenously partitions the parameter space into the determinate and indeterminate region, and deals with the possibility of multiple degrees of indeterminacy. Hence, this methodology substantially simplifies the approach to test for indeterminacy in U.S. monetary policy. I show that the assumption is rejected before 1979 and monetary policy was passive, even when accounting for a richer model.

The method proposes to augment the original model with a set of auxiliary equations that are used to provide the adequate number of explosive roots in presence of indeterminacy. The augmented representation also introduces a non-fundamental sunspot shock to construct the solution under indeterminacy. The characterization of the full set of equilibria under indeterminacy is parametrized by the additional parameters related to the standard deviation of the sunspot shock and its covariance with the structural shock of the model.

This augmented representation provides three main advantages. First, it accommodates both the case of determinacy and indeterminacy, while considering the same augmented system of equations. In particular, the solution in this expanded state space, if it exists, is always determinate, and is identical to the indeterminate solution of the original model. The model can therefore be solved by using standard solution algorithms. Second, given that the method accommodates both the case of determinacy and indeterminacy, the researcher does not need to take a stance on which area of the parameter space she is interested in exploring. Finally, even when the region of determinacy is unknown as in the case of medium-scale models, the methodology allows the researcher to estimate the model without imposing *a priori* assumptions about the uniqueness of the equilibrium. Information contained in the data indicates whether an estimated model is characterized by a unique solution or by multiplicity of equilibrium paths.

While Section 5.1 provides a simple analytical example to explain the methodology developed in Bianchi and Nicolò (2017), Section 5.2 describes how I implement it to test for indeterminacy in U.S. monetary policy in the richer medium-scale model by SW.

## 5.1 Building the Intuition

I consider a simple analytical example to present the technical complexities that a researcher faces when dealing with indeterminacy and to provide an intuition for how the methodology developed in Bianchi and Nicolò (2017) simplifies the construction of the solution under indeterminacy. Recalling the classical monetary model in Section 3.2, I report below the corresponding univariate representation

$$E_t(\pi_{t+1}) = \phi_\pi \pi_t - r_t. \tag{15}$$

As previously described, the solution to this model depends on the conduct of monetary policy. If the monetary authority is active, $|\phi_\pi| > 1$, the determinate solution is

$$\pi_t = \frac{1}{\phi_\pi} r_t. \tag{16}$$

Alternatively, if the monetary authority is passive, $|\phi_\pi| \leq 1$, the indeterminate solution is any process that takes the following form

$$\pi_t = \phi_\pi \pi_{t-1} - r_{t-1} + \eta_t. \tag{17}$$

The problem that a researcher faces when dealing with the indeterminate solution of a LRE model such as the one presented in (15) is the following. The equilibrium dynamics are uniquely determined if the Blanchard-Kahn condition is satisfied (Blanchard and Kahn, 1980). The condition requires the number of expectational variables of the model to equal the number of its unstable roots. The endogenous variable of the univariate model in (15) is expectational and the dynamics properties of the model depends on the value assumed by $\phi_\pi$. When $|\phi_\pi| > 1$, the model has a unique solution since it has a sufficient number of unstable roots to match the number of expectational variables. However, when $|\phi_\pi| \leq 1$, the model is indeterminate since it is missing one explosive root. The latter case constitutes a challenge because standard software packages do not deal with indeterminacy.

The approach in Bianchi and Nicolò (2017) proposes to augment the original model by appending an independent process which could be either stable or unstable. The key insight consists of choosing this auxiliary process in a way to deliver the correct solution. When the original model is determinate, the auxiliary process must be stationary so that also the augmented representation satisfies the Blanchard-Kahn condition. When the model is indeterminate, the additional process should however be explosive so that the Blanchard-Kahn condition is satisfied for the augmented system, even if it is not for the original model. In what follows, I apply this intuition to the example considered in this section and explain how to choose the auxiliary process.

Considering the univariate example in (15), the methodology of Bianchi and Nicolò (2017) proposes to solve the following augmented system of equations

$$\begin{cases} E_t(\pi_{t+1}) = \phi_\pi \pi_t - r_t, \\ \omega_t = \left(\frac{1}{\alpha}\right) \omega_{t-1} - \nu_t + \eta_t, \end{cases} \tag{18}$$

where $\omega_t$ is an auxiliary autoregressive process, $\alpha \in [0, 2]$, $\nu_t$ is a newly defined mean-zero sunspot shock with standard deviation $\sigma_v$ and $\eta_t$ still denotes the forecast errors, $\eta_t =$

| | Unstable Roots | B-K condition in augmented model (18) | Solution |
|---|---|---|---|
| Determinacy $\lvert\phi_\pi\rvert > 1$ in original model (15) | | | |
| $\frac{1}{\alpha} < 1$ | 1 | Satisfied | $\left\{\pi_t = \frac{1}{\phi_\pi} r_t,\ \omega_t = \alpha\omega_{t-1} - \nu_t + \varepsilon_t\right\}$ |
| $\frac{1}{\alpha} > 1$ | 2 | Not satisfied | - |
| Indeterminacy $\lvert\phi_\pi\rvert \leq 1$ in original model (15) | | | |
| $\frac{1}{\alpha} < 1$ | 0 | Not satisfied | -$\{\ \omega_t = 0\}$ |
| $\frac{1}{\alpha} > 1$ | 1 | Satisfied | $\left\{\begin{array}{cc} \pi_t = \phi_\pi \pi_{t-1} - r_{t-1} + \eta_t, & \\ \eta_t = v_t, & \omega_t = 0 \end{array}\right\}$ |

Table 1: The table reports the regions of the parameter space for which the Blanchard-Kahn condition in the augmented representation is satisfied, even when the original model is indeterminate.

$\pi_t - E_{t-1}(\pi_t)$ as in the original model.[14]

Table 1 summarizes the intuition behind the approach. When the original LRE model in (15) is determinate, $|\phi_\pi| > 1$, the Blanchard-Kahn condition for the augmented representation in (18) is satisfied when $|1/\alpha| \leq 1$. Indeed, for $|\phi_\pi| > 1$ the original model has the same number of unstable roots as the number of expectational variables. The methodology thus suggests to append a stable autoregressive process and standard solution methods deliver the same solution for the endogenous variable $\pi_t$ as in equation (16). Since the coefficient $|1/\alpha|$ is smaller than 1, the solution for the augmented representation also includes the autoregressive process $\omega_t$. Importantly, its dynamics do not impact the endogenous variable $y_t$.

Considering the case of indeterminacy (i.e. $|\phi_\pi| \leq 1$), the original model has one expectational variable, but no unstable root, thus violating the Blanchard-Kahn condition. If the autoregressive process is explosive (i.e. $|1/\alpha| > 1$), the augmented representation satisfies the Blanchard-Kahn condition and delivers the same solution for $\pi_t$ as in equation (17). Moreover, to guarantee boundedness, the solution imposes conditions such that $\omega_t$ is always equal to zero, and the solution for the endogenous variable, $\pi_t$, does not depend on the appended autoregressive process.

Summarizing, the choice of the additional parameter $\alpha$ should be made as follows. For values of $|\phi_\pi|$ outside the unit circle, the Blanchard-Kahn condition for the augmented represen-

[14]The choice of parametrizing the auxiliary process with $1/\alpha$ instead of $\alpha$ induces a positive correlation between $\phi_\pi$ and $\alpha$ that facilitates the implementation of the method when estimating a model.

tation is satisfied for values of $|1/\alpha|$ smaller than 1. Conversely, under indeterminacy (i.e. $|\phi_\pi| \leq 1$) the condition is satisfied when $|1/\alpha|$ is greater than 1. Also, note that under both determinacy and indeterminacy, the exact value of $1/\alpha$ is irrelevant for the law of motion of $\pi_t$. Under determinacy, the auxiliary process $\omega_t$ is stationary, but its evolution does not affect the law of motion of the model variables. Under indeterminacy, $\omega_t$ is always equal to zero. Hence, the introduction of the auxiliary processes does not affect the properties of the solution in either case. These processes only serve the purpose of providing the necessary explosive roots under indeterminacy and creating the mapping between the sunspot shocks and the expectational errors.

### 5.2 Implementation to Smets and Wouters (2007)

When adopting a univariate model such as in Section 5.1 or a small-scale model such as the NK model in LS, a researcher derives analytically the condition which partitions the parameter space into a determinate and indeterminate region. Also, she studies the dynamic properties of the model and determines the maximum degree of indeterminacy of the model. To implement the methodology developed in Bianchi and Nicolò (2017) to medium-scale models such as SW, a researcher faces the following technical complexities. It is not possible to derive analytically the partition of the parameter space, and the researcher does not know the exact properties of the determinacy region. Also, the adoption of a medium-scale model implies that a researcher does not know the degree of indeterminacy which characterizes the model.

To overcome these complexities, Bianchi and Nicolò (2017) indicate the following steps. First, the researcher should note that, for any model with $p$ expectational variables, then the maximum degree of indeterminacy also corresponds to $p$. Defining $\{\eta_{i,t}\}_{i=1}^{p}$ to be the forecast errors associated with each expectational variable, the original LRE model should be augmented by appending up to $p$ exogenous processes $\omega_{i,t} = \left(\frac{1}{\alpha_i}\right)\omega_{i,t-1} - \nu_{i,t} + \eta_{i,t}$ for $i = 1, .., p$. Second, the researcher cannot derive the partition of the parameter space analytically. For a given draw of the structural parameters of the model, the researcher would like to make draws of $\alpha_i$ smaller or greater than 1 with equal probabilities. Therefore, to implement this methodology to the model of SW, I assume a uniform distribution over the interval $[0.9, 1.1]$ as a prior distribution.[15] Third, while the newly defined shocks, $\{\nu_{i,t}\}_{i=1}^{p}$, are independent, they are potentially related to the structural shocks of the model. Hence, I assume a uniform distribution over the interval $[-1, 1]$ for the correlations between the

[15]Note that any symmetric interval around 1 also guarantees an equal probability of drawing $\alpha$ greater or smaller than 1. Alternatively, a researcher could assume a discrete distribution for which $\alpha$ could assume only two values (one inside the unit circle and one outside) with equal probabilities. However, this option is not implementable in standard software packages such as Dynare, since only continuous distributions are available as possible choice of prior distribution for the model parameters.

newly defined shocks, $\{\nu_{i,t}\}_{i=1}^{p}$, and the seven structural shocks that impact the economy as described in Section 4.[16]

Following these steps, I find that the data favors a specification with one degree of indeterminacy. Hence, the augmented representation that I use to present the findings only includes one auxiliary process, $\omega_t$. Also, the data indicates that the non-fundamental shock included in the augmented representation is the forecast error associated with the inflation rate $\eta_{\pi,t} \equiv \pi_t - E_{t-1}(\pi_t)$. In Section 6.1 I estimate the SW model augmented with the exogenous process $\omega_t = \left(\frac{1}{\alpha}\right)\omega_{t-1} - \nu_t + \eta_{\pi,t}$, where the newly defined sunspot shock, $\nu_t$, could potentially be correlated with the seven structural shocks of the model. The estimation also shows that, according to the data, the correlation between the sunspot shock and the price mark-up shock is the only statistically significant.

# 6 Main Findings

I show that monetary policy was passive between 1955 and 1979, and active since 1984. As a result, the imposition of an active monetary policy as in SW delivers erroneous estimates of the structural parameters. I also analyze the conduct of U.S. monetary policy during the period between the collapse of the dot-com bubble and the Great Recession. The evidence of a passive monetary policy in a conventional three-equation NK model is instead ruled out when accounting for the rich dynamic and stochastic structure of the SW model.

I document the effects of a change in monetary policy on the dynamics of the economy and the transmission of structural shocks. When monetary policy is passive, the propagation of structural shocks is altered and more persistent due to the formation of self-fulfilling expectations. In this regime, a productivity shock still generates economic activity by decreasing the marginal cost incurred by the firms. However, the shock is also associated with the formation of persistent, inflationary expectations that more than offset the drop in marginal cost and finally result into self-fulfilling inflationary pressures.

Fundamental productivity and cost shocks were the primary drivers of the run-up in the inflation rate from the early 1960s to 1979. Positive technology shocks in the 1960s de-anchored

[16] From a technical perspective, the parameters which characterize the full set of indeterminate equilibria in LS relate to the covariances between the structural shocks of the model and a newly defined shock that their solution method introduces. As shown in Bianchi and Nicolò (2017), there is a unique mapping between their parametrization of the set of equilibria and the covariances which arise in this paper between the sunspot shock, $\nu_t$, and the remaining structural shocks of the model. However, the additional parameters introduced in LS do not have a well-defined domain and the authors discipline the normal prior distributions for these parameters by centering them around the point estimates that minimize the distance between the impulse responses under determinacy and indeterminacy. On the contrary, the methodology of Bianchi and Nicolò (2017) that I adopt in this paper allows to deal with correlations, that are well-defined in the interval $[-1, 1]$ and for which a uniform distribution can be used as a prior.

inflation expectations from the central bank's long-run target and generated persistent inflationary pressures via self-fulfilling expectations. Mark-up shocks account for the sudden inflationary episodes related to the oil crisis during the 1970s, while they are not significant drivers of the rise in inflation during the 1960s. On the contrary, previous studies that impose an active monetary policy before 1979 exclude the role of self-fulfilling expectations for the transmission of structural shocks. The persistent rise in inflation from the early 1960s through the 1970s would be entirely and erroneously attributed to mark-up shocks. Moreover, the high volatility of inflation and output growth before 1979 was caused by fundamental disturbances, and non-fundamental sunspot shocks were not significant drivers of volatility between 1955 and 1979.

Finally, I revisit the question about the sources of the reduction in U.S. macroeconomic volatility between the early 1980s to 2007. Based on the SW model, I find that the reduction in macroeconomic uncertainty was a combination of both a change in monetary policy to a more active stance *and* a lower volatility of the shocks.

## 6.1 U.S. Monetary Policy in the Post-War Period

Section 6.1.1 provides evidence of a change in the conduct of monetary policy in the post-war period, from a passive stance before 1979 to an active inflation targeting since the early 1980s. This results has two implications. First, the assumption imposed in SW about an active monetary policy both before and after 1979 is rejected. Second, the findings in previous studies that adopted univariate or small-scale models (Clarida et al., 2000, Lubik and Schorfheide, 2004) carry over to the SW model.

The section provides two additional findings. First, in Section 6.1.2 I show that, if a researcher assumes an active monetary policy before 1979, she would find erroneous estimates of the structural parameters, especially related to the persistence in inflation dynamics. The data would mistakenly indicate a higher degree of wage and inflation indexation as well as more persistence of the price mark-up shock.

Second, in Section 6.1.3 I shed light on the debate about whether the conduct of monetary policy after the dot-com bubble led to economic conditions that facilitated the occurrence of the Great Recession. I show that the results are susceptible to the modeling choice of the researcher due to the identification problem presented in Section 3.1. While the conventional three-equation NK model in LS rationalizes the data with a passive monetary policy, the adoption of the richer dynamic and stochastic structure in the SW model overturns this conclusion and indicates the conduct of an active monetary policy.

### 6.1.1 Changes in the Conduct of U.S. Monetary Policy

This section provides evidence of the change in the conduct of U.S. monetary policy in the post-war period. By considering the model and the data described in Section 4, I apply the methodology presented in Section 5 to estimate the SW model over three subsamples. The first period starts in 1955:4, which corresponds to one year after the end of the Korean War, and it ends in 1969:4, the date in which the chairmanship of William Martin terminates. The second sample considers the chairmanships of both Arthur Burns and William Miller, and it spans from 1970:1 until 1979:2. Finally, the beginning of the third period corresponds to 1984:1, in which Kim and Nelson (1999) initially identify a structural break in the U.S. business cycle, while the end is marked by the Great Recession in 2007:3.[17]

Appendix A reports the prior distributions for the structural parameters of the model and the exogenous processes that drive the dynamics of the economy. Relative to the prior distributions used in SW, the only difference relates to the Taylor rule coefficient associated with the response of the monetary authority to changes in the inflation rate. While SW specify a normal distribution truncated at 1, centered at 1.50 and with standard deviation 0.25, I consider a prior which assigns an approximately equal probability of observing indeterminacy as well as a unique solution. In particular, I set a flatter normal prior distribution centered at 1 and with standard deviation 0.35.

As discussed in Section 5.2, I estimate the model implementing the methodology developed in Bianchi and Nicolò (2017) and using Bayesian techniques. The data favors a specification with one degree of indeterminacy and in which the non-fundamental shock included in the augmented representation is the forecast error associated with the inflation rate $\eta_{\pi,t} \equiv \pi_t - E_{t-1}(\pi_t)$. Therefore, I estimate the SW model augmented it with the exogenous process $\omega_t = \left(\frac{1}{\alpha}\right)\omega_{t-1} - \nu_t + \eta_{\pi,t}$. For the parameter $\alpha$, I assume a uniform prior distribution over the interval $[0.9, 1.1]$ and I also specify a uniform prior distribution over the interval $[0, 1]$ for the standard deviation of the sunspot shock, $\sigma_\nu$.[18] Moreover, the data favors a specification in which the sunspot shock, $\nu_t$, is correlated with price mark-up shock, while restricting the remaining correlations to 0. For the estimation, I therefore use a uniform distribution over the interval $[-1, 1]$ as the prior for the correlation between the price mark-up shock and the sunspot shock.[19]

[17] The findings in this section for the period prior to 1979:2 are quantitatively unchanged when considering a sample spanning from 1955:4 until 1979:2. However, studying the two samples separately is relevant to understand the connection between different steady state properties between the two periods and the exceptional growth in productivity until the early 1970s documented in Fernald (2014a).

[18] As shown in Table 4, the posterior distribution for the sunspot shock is not at the boundary but rather interior to the interval over which the uniform prior distribution.

[19] The reader is referred to Section 5.2 for the technical details of the implementation of the methodology presented in Bianchi and Nicolò (2017) to medium-scale model of SW.

Table 2 reports the results of the estimation for each subsample. Relative to SW, the novelty is to relax the *a priori* assumption of equilibrium uniqueness. The method described in Section 5 allows to estimate the model over the entire parameter space. For each period, the Metropolis-Hastings algorithm finds two local maxima, one associated with the determinate solution and the other with the indeterminate representation. It is therefore possible to compute the corresponding marginal data density using the modified harmonic mean estimator proposed by Geweke (1999) and the posterior model probabilities associated with each local maxima. Focusing on the first two samples that cover the period from 1955:4 to 1979:2, the data strongly favors the representation associated with indeterminacy, therefore rejecting the assumption of equilibrium uniqueness imposed in SW. On the contrary, the period subsequent to the Volcker disinflation is associated with a determinate, unique representation.

| | | Determinacy | Indeterminacy |
|---|---|---|---|
| Martin (55Q4 - 69Q4) | Log data density | -278.38 | -272.50 |
| | Posterior Model Prob (%) | 0.0% | 100.0% |
| Burns-Miller (70Q1 - 79Q2) | Log data density | -337.23 | -319.29 |
| | Posterior Model Prob (%) | 0.0% | 100.0% |
| Post-Volcker (84Q1 - 07Q3) | Log data density | -399.85 | -406.88 |
| | Posterior Model Prob (%) | 100.0% | 0.0% |

Table 2: The table reports the (log) data densities and the posterior model probabilities obtained for each sample period.

The evidence of a change in the monetary policy stance since 1984:1 is presented in Table 3, where the posterior distributions of the structural parameters in the three sub-periods are compared.[20] Considering the Taylor rule coefficient associated with the response of the monetary authority to changes in the inflation rate, $r_\pi$, it is clear that the monetary authority was passive prior to 1979, thus consistent with a weak response of the monetary authority to changes in the inflation rate. Table 3 also suggests that for the period subsequent to the Volcker disinflation, the monetary authority changed its stance and acted more aggressively to stabilize inflation, therefore ensuring equilibrium uniqueness.

Importantly, these results provide evidence that, even when accounting for the richer propagation mechanisms, equilibrium was indeterminate before 1979, and the findings of Clarida et al. (2000) and LS among others carry over to a medium-scale model.

Table 3 also provides evidence in support of Fernald (2014a) who documents that the U.S. economy experienced a period of exceptional growth in productivity in the post-war period

[20] I consider the posterior estimates to be unchanged when the posterior mean of a parameter estimated in either of the two sample periods is within the 90% probability interval associated with the posterior distribution obtained in the alternative sample.

until the early 1970s. Both the trend growth rate of the economy and the (steady state) hours worked drop significantly in the period between 1970 until 1979 relative to the previous period. The posterior distributions also show that the post-Volcker period is characterized by a mildly higher degree of price stickiness, $\xi_p$, and a more persistent process of the price-markup shock measured by $\rho_p$ in Table 4. This finding is supported by Galí and Gertler (1999), who provide evidence of an increased average price duration over this period due to the lower and more stable inflation rate. Also, the post-Volcker period is associated with a larger adjustment cost faced by the representative agent that chooses a higher degree of capital utilization rate.

| | | 1955:4-1969:4 | | 1970:1-1979:2 | | 1984:1-2007:3 | |
|---|---|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $\phi$ | Adjustment cost | 4.58 | [2.68,6.38] | 3.41 | [2.01,4.64] | 6.95 | [5.20,8.73] |
| $\sigma_c$ | IES | 1.13 | [0.85,1.40] | 0.91 | [0.67,1.15] | 1.61 | [1.38,1.84] |
| $h$ | Habit Persistence | 0.60 | [0.48,0.73] | 0.62 | [0.49,0.76] | 0.65 | [0.57,0.73] |
| $\sigma_l$ | Labor supply elasticity | 1.98 | [0.93,3.07] | 1.29 | [0.25,2.15] | 2.29 | [1.33,3.22] |
| $\xi_w$ | Wage stickiness | 0.73 | [0.62,0.84] | 0.70 | [0.59,0.81] | 0.68 | [0.53,0.83] |
| $\xi_p$ | Price Stickiness | 0.59 | [0.51,0.67] | 0.58 | [0.50,0.65] | 0.75 | [0.67,0.83] |
| $\iota_w$ | Wage Indexation | 0.33 | [0.14,0.53] | 0.57 | [0.36,0.78] | 0.44 | [0.20,0.68] |
| $\iota_p$ | Price Indexation | 0.29 | [0.12,0.45] | 0.48 | [0.25,0.73] | 0.28 | [0.10,0.44] |
| $\psi$ | Capacity utiliz. elasticity | 0.55 | [0.36,0.75] | 0.49 | [0.26,0.72] | 0.71 | [0.57,0.86] |
| $\Phi$ | Share of fixed costs | 1.59 | [1.46,1.72] | 1.34 | [1.18,1.50] | 1.60 | [1.46,1.75] |
| $\alpha$ | Share of capital | 0.24 | [0.19,0.29] | 0.18 | [0.13,0.23] | 0.23 | [0.19,0.26] |
| $\bar{\pi}$ | S.S. inflation rate (quart.) | 0.62 | [0.45,0.78] | 0.62 | [0.46,0.77] | 0.68 | [0.55,0.80] |
| $100(\beta^{-1}-1)$ | Discount factor | 0.17 | [0.06,0.27] | 0.21 | [0.08,0.33] | 0.13 | [0.05,0.21] |
| $\bar{l}$ | S.S. hours worked | 1.36 | [0.21,2.53] | -2.37 | [-3.58,-1.05] | 1.57 | [0.36,2.80] |
| $\bar{\gamma}$ | Trend growth rate (quart.) | 0.47 | [0.40,0.53] | 0.36 | [0.32,0.41] | 0.45 | [0.42,0.48] |
| $r_\pi$ | Taylor rule inflation | 0.64 | [0.32,0.98] | 0.75 | [0.54,0.99] | 1.80 | [1.39,2.20] |
| $r_y$ | Taylor rule output gap | 0.13 | [0.05,0.20] | 0.16 | [0.09,0.23] | 0.09 | [0.03,0.14] |
| $r_{\Delta y}$ | Taylor rule $\Delta$(output gap) | 0.11 | [0.07,0.15] | 0.18 | [0.12,0.24] | 0.15 | [0.10,0.19] |
| $\rho$ | Taylor rule smoothing | 0.87 | [0.81,0.95] | 0.73 | [0.60,0.86] | 0.84 | [0.80,0.88] |

Table 3: The table compares the posterior estimates of structural parameters under indeterminacy for the pre-Volcker and under determinacy for the post-Volcker period.

Finally, the comparison in Table 4 of the properties of the exogenous processes between the period before and after 1979 provides an additional finding. In line with a large literature, the volatility of the shocks that drive fluctuations of the economy are significantly smaller starting from the mid 1980s (Stock and Watson, 2003, Primiceri, 2005, Sims and Zha, 2006). This result and the evidence of the change in the conduct of monetary policy are clearly linked to the discussion on the possible explanations for the sources of the reduction in U.S.

macroeconomic volatility from the early 1980s to 2007. In Section 6.4, I show that, according to the SW model, both the change in the monetary policy stance *and* the lower size of the shocks explain this empirical observation for U.S. macro data.

| | | 1955:4-1969:4 | | 1970:1-1979:2 | | 1984:1-2007:3 | |
|---|---|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $\sigma_a$ | Technology shock | 0.52 | [0.44,0.61] | 0.56 | [0.45,0.67] | 0.36 | [0.31,0.40] |
| $\sigma_b$ | Risk premium shock | 0.19 | [0.11,0.27] | 0.17 | [0.10,0.23] | 0.18 | [0.14,0.22] |
| $\sigma_g$ | Government sp. shock | 0.51 | [0.43,0.59] | 0.55 | [0.44,0.65] | 0.41 | [0.36,0.46] |
| $\sigma_I$ | Investment-specific shock | 0.60 | [0.42,0.77] | 0.38 | [0.23,0.53] | 0.35 | [0.28,0.43] |
| $\sigma_r$ | Monetary policy shock | 0.11 | [0.09,0.12] | 0.22 | [0.18,0.26] | 0.12 | [0.10,0.14] |
| $\sigma_p$ | Price mark-up shock | 0.24 | [0.20,0.29] | 0.31 | [0.24,0.39] | 0.09 | [0.07,0.11] |
| $\sigma_w$ | Wage mark-up shock | 0.24 | [0.19,0.28] | 0.31 | [0.23,0.38] | 0.31 | [0.24,0.37] |
| $\sigma_\nu$ | Sunspot shock | 0.14 | [0.07,0.21] | 0.19 | [0.06,0.33] | - | - |
| $\rho_a$ | Persistence technology | 0.95 | [0.92,0.99] | 0.73 | [0.60,0.87] | 0.92 | [0.87,0.97] |
| $\rho_b$ | Persistence risk premium | 0.59 | [0.35,0.84] | 0.77 | [0.62,0.92] | 0.20 | [0.05,0.35] |
| $\rho_g$ | Persistence government sp. | 0.86 | [0.78,0.94] | 0.85 | [0.77,0.94] | 0.96 | [0.94,0.98] |
| $\rho_I$ | Persistence investment-specific | 0.50 | [0.30,0.70] | 0.65 | [0.47,0.84] | 0.64 | [0.52,0.76] |
| $\rho_r$ | Persistence monetary policy | 0.50 | [0.31,0.68] | 0.32 | [0.11,0.51] | 0.37 | [0.21,0.52] |
| $\rho_p$ | Persistence price mark-up | 0.24 | [0.04,0.43] | 0.39 | [0.11,0.65] | 0.83 | [0.72,0.95] |
| $\rho_w$ | Persistence wage mark-up | 0.63 | [0.36,0.91] | 0.42 | [0.14,0.68] | 0.81 | [0.66,0.95] |
| $\mu_p$ | MA price mark-up | 0.64 | [0.43,0.85] | 0.70 | [0.45,0.95] | 0.66 | [0.48,0.84] |
| $\mu_w$ | MA wage mark-up | 0.50 | [0.27,0.75] | 0.56 | [0.26,0.88] | 0.61 | [0.38,0.82] |
| $\rho_{ga}$ | $Cov(\sigma_a, \sigma_g)$ | 0.59 | [0.39,0.78] | 0.62 | [0.40,0.84] | 0.40 | [0.22,0.57] |
| $\rho_{\nu p}$ | $Corr(\sigma_\nu, \sigma_p)$ | 0.92 | [0.82,0.99] | 0.69 | [0.37,0.99] | - | - |

Table 4: The table compares the posterior estimates of the parameters associated with the exogenous processes under indeterminacy for the pre-Volcker and under determinacy for the post-Volcker period.

### 6.1.2 The Impact of the SW Restriction

This subsection studies the implications of the *a priori* restriction about equilibrium uniqueness imposed in SW for the study of U.S. business cycle fluctuations. As shown in Table 2, the assumption is validated by the data exclusively for the post-Volcker period. On the contrary, the restriction is rejected when considering the sample prior to 1979. Table 5 reports the posterior distribution of the structural parameters estimated for each of the two local maxima found by the Metropolis-Hastings algorithm for the first sample period (1955:4-1969:4). The table allows for a comparison with the estimation results that would be obtained by imposing the same *a priori* assumption as in SW.[21] While most of the estimates are unchanged, relaxing the restriction implies that the Taylor rule coefficient on inflation is estimated to be associated with a weak response of the monetary authority, therefore rejecting the assumption imposed in SW. As shown in Section 6.2 and 6.3, this finding has crucial implications for the propagation of the shocks and to explain U.S. business cycle fluctuations.

The comparison of the posterior estimates also highlights a higher degree of both the wage and inflation indexation, as well as more persistence of the price mark-up shock. This finding is in line with the intuition provided in Section 3.1. A characteristic feature of indeterminate models is their richer endogenous persistence. Hence, when imposing the assumption of an active monetary policy, the model incurs a difficulty in matching the observed persistence in the data and mistakenly suggests a higher persistence than in the representation favored by the data.

| Period: 1955:4-1969:4 | | Indeterminacy | | Determinacy | |
|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $\phi$ | Adjustment cost | 4.58 | [2.68,6.38] | 4.95 | [3.11,6.74] |
| $\sigma_c$ | IES | 1.13 | [0.85,1.40] | 1.18 | [0.81,1.55] |
| $h$ | Habit Persistence | 0.60 | [0.48,0.73] | 0.61 | [0.44,0.79] |
| $\sigma_l$ | Labor supply elasticity | 1.98 | [0.93,3.07] | 1.43 | [0.35,2.34] |
| $\xi_w$ | Wage stickiness | 0.73 | [0.62,0.84] | 0.76 | [0.67,0.84] |
| $\xi_p$ | Price Stickiness | 0.59 | [0.51,0.67] | 0.62 | [0.50,0.73] |
| $\iota_w$ | Wage Indexation | 0.33 | [0.14,0.53] | 0.43 | [0.20,0.65] |
| $\iota_p$ | Price Indexation | 0.29 | [0.12,0.45] | 0.39 | [0.12,0.68] |
| $\psi$ | Capacity utiliz. elasticity | 0.55 | [0.36,0.75] | 0.46 | [0.25,0.66] |
| $\Phi$ | Share of fixed costs | 1.59 | [1.46,1.72] | 1.62 | [1.46,1.78] |
| $\alpha$ | Share of capital | 0.24 | [0.19,0.29] | 0.24 | [0.20,0.29] |
| $\bar{\pi}$ | S.S. inflation rate (quart.) | 0.62 | [0.45,0.78] | 0.62 | [0.48,0.75] |
| $100(\beta^{-1}-1)$ | Discount factor | 0.17 | [0.06,0.27] | 0.18 | [0.06,0.29] |
| $\bar{l}$ | S.S. hours worked | 1.36 | [0.21,2.53] | 2.03 | [0.72,3.47] |
| $\bar{\gamma}$ | Trend growth rate (quart.) | 0.47 | [0.40,0.53] | 0.47 | [0.29,0.60] |
| $r_\pi$ | Taylor rule inflation | 0.64 | [0.32,0.98] | 1.37 | [0.99,1.71] |
| $r_y$ | Taylor rule output gap | 0.13 | [0.05,0.20] | 0.14 | [0.06,0.23] |
| $r_{\Delta y}$ | Taylor rule $\Delta$(output gap) | 0.11 | [0.07,0.15] | 0.12 | [0.08,0.17] |
| $\rho$ | Taylor rule smoothing | 0.87 | [0.81,0.95] | 0.87 | [0.82,0.92] |

Table 5: The table compares the posterior estimates of structural parameters for the pre-Volcker period under indeterminacy and determinacy.

[21]Similar differences arise when using the second subsample (1970:1-1979:2) to study how the imposition of the assumption in SW would impact the results.

| Period: 1955:4-1969:4 | | Indeterminacy | | Determinacy | |
|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $\sigma_a$ | Technology shock | 0.52 | [0.44,0.61] | 0.53 | [0.43,0.62] |
| $\sigma_b$ | Risk premium shock | 0.19 | [0.11,0.27] | 0.17 | [0.05,0.29] |
| $\sigma_g$ | Government sp. shock | 0.51 | [0.43,0.59] | 0.50 | [0.42,0.58] |
| $\sigma_I$ | Investment-specific shock | 0.60 | [0.42,0.77] | 0.58 | [0.40,0.75] |
| $\sigma_r$ | Monetary policy shock | 0.11 | [0.09,0.12] | 0.11 | [0.09,0.14] |
| $\sigma_p$ | Price mark-up shock | 0.24 | [0.20,0.29] | 0.22 | [0.15,0.29] |
| $\sigma_w$ | Wage mark-up shock | 0.24 | [0.19,0.28] | 0.24 | [0.19,0.30] |
| $\sigma_\nu$ | Sunspot shock | 0.14 | [0.07,0.21] | - | - |
| $\rho_a$ | Persistence technology | 0.95 | [0.92,0.99] | 0.93 | [0.85,0.99] |
| $\rho_b$ | Persistence risk premium | 0.59 | [0.35,0.84] | 0.64 | [0.17,0.98] |
| $\rho_g$ | Persistence government sp. | 0.86 | [0.78,0.94] | 0.85 | [0.74,0.96] |
| $\rho_I$ | Persistence investment-specific | 0.50 | [0.30,0.70] | 0.53 | [0.33,0.74] |
| $\rho_r$ | Persistence monetary policy | 0.50 | [0.31,0.68] | 0.44 | [0.27,0.60] |
| $\rho_p$ | Persistence price mark-up | 0.24 | [0.04,0.43] | 0.64 | [0.22,0.98] |
| $\rho_w$ | Persistence wage mark-up | 0.63 | [0.36,0.91] | 0.52 | [0.22,0.81] |
| $\mu_p$ | MA price mark-up | 0.64 | [0.43,0.85] | 0.75 | [0.46,0.99] |
| $\mu_w$ | MA wage mark-up | 0.50 | [0.27,0.75] | 0.47 | [0.19,0.75] |
| $\rho_{ga}$ | $Cov(\sigma_a, \sigma_g)$ | 0.59 | [0.39,0.78] | 0.56 | [0.37,0.76] |
| $\rho_{\nu p}$ | $Corr(\sigma_\nu, \sigma_p)$ | 0.92 | [0.82,0.99] | - | - |

Table 6: The table compares the posterior estimates of the parameters associated with the exogenous processes for the pre-Volcker period under indeterminacy and determinacy.

### 6.1.3 The Federal Reserve Leading to the Great Recession?

The framework considered in this paper also allows to shed light on the recent debate on the conduct of U.S. monetary policy during the period between the collapse of the dot-com bubble and the Great Recession. On the one hand, Taylor (2012) considers the headline consumer price index (CPI) to measure the inflation rate and suggests that, by keeping the federal fund rate too low relative to a conventional Taylor rule since the 2001, the Fed generated economic conditions which led to the Great Recession. On the other hand, Bernanke (2015) constructs a measure of inflation using the core personal consumption expenditure deflator (PCE) and finds that the Fed reacted as prescribed by a conventional Taylor rule to changes in the inflation rate.

Doko Tchatoka et al. (2017) assess the performance of the Fed by using a structural approach and in particular a conventional three-equation NK model in the spirit of LS. The authors find that monetary policy was active only when the inflation rate is measured with core PCE. However, when the same analysis is conducted using headline CPI to measure inflation, the evidence of equilibrium indeterminacy cannot excluded.

In this section, I argue that, after accounting for the richer dynamic and stochastic structure of the SW model, the evidence of a passive monetary is overturned. As in Doko Tchatoka et al. (2017), I focus on the period between the 2001 slump and the onset of the Great Recession (2002:1-2007:3) and I use the GDP deflator to measure inflation as in SW. However, I address the question about the conduct of U.S. monetary policy by estimating both the small-scale model in LS and the medium-scale model of SW.[22]

Table 7 reports the (log) data densities and the corresponding marginal data densities for the determinate and indeterminate representations using two alternative models. The first row is in line with the result of Taylor (2012) and Doko Tchatoka et al. (2017). By estimating the small-scale model of LS, the data provides evidence of indeterminacy with a posterior probability of 78.8%. Nevertheless, the conclusion is reversed once richer and more relevant propagation mechanisms and structural shocks are included. According to the SW model, monetary policy was active and consistent with a determinate equilibrium. Finally, Table 7 provides an empirical example of the identification problem described in Section 3.1 for which missing propagation mechanisms could be misinterpreted as evidence of indeterminacy.

| Sample: 2002:1-2007:3 | | Determinacy | Indeterminacy |
|---|---|---|---|
| LS model | Log data density | -20.48 | -19.16 |
| | Posterior Model Prob (%) | 21.2% | 78.8% |
| SW model | Log data density | -122.20 | -125.76 |
| | Posterior Model Prob (%) | 97.2% | 2.8% |

Table 7: The table reports the (log) data densities and the posterior model probabilities for the LS model and the SW model using the sample period 2002:1-2007:3.

## 6.2 Monetary Policy, Expectations and the Propagation Mechanism

In this section, I focus on the implications that the observed change in the stance of monetary policy has on the transmission of the structural shocks of the SW model. In particular, I study the propagation of three shocks that, as highlighted in Section 6.3, explain most of U.S. business cycle fluctuations in the period prior to 1979: productivity, risk-premium and

[22]Regarding the estimation of the SW model, I use the same model as in the Section 4 and I restrict the data to consider the sample under study. The LS model is described in Section 6.4 and I use the same data as for SW for the observables of the model: the output gap, the inflation rate and the nominal interest rate. As a note, since the SW model assumes the uncorrelation of the structural shocks (except the productivity and government spending shocks), I also assume that the structural shocks of the LS model (mark-up, demand and monetary policy shocks) are uncorrelated.

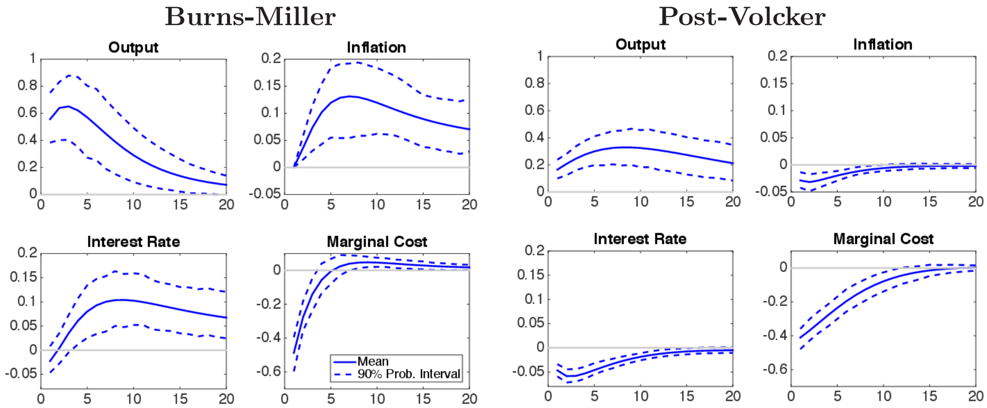


Figure 1: Mean impulse responses to a productivity shock are denoted by solid lines, while dashed lines represent the associated 90% probability intervals.

monetary policy shocks.[23]

**Productivity Shock** The impact of a productivity shock has implications that differ depending on the conduct of U.S. monetary policy. The four panels on the right of Figure 1 show the transmission of a (one standard deviation) productivity shock in the post-Volcker period on the output gap, the inflation rate, the nominal interest rate and the marginal cost incurred by firms.[24] The shock generates economic activity and deflationary pressures due to a drop in marginal cost. Under the active inflation targeting, the monetary authority responds by lowering the policy rate by more than one-for-one. Conversely, the four panels on the left are associated with the passive monetary policy of the Burns and Miller chairmanship. The shock still results into a drop in marginal costs and an economic expansion. However, the productivity shock also generates inflationary expectations that are not suppressed by the passive monetary authority and more than compensate the drop in marginal cost. This mechanism thus results into a self-fulfilling rise of the inflation rate.[25] The corresponding increase in the nominal interest rate is gradual and not aggressive enough to stabilize the inflation rate, therefore allowing for persistent effects on the economy.

[23]Regarding the remaining shocks, either the propagation mechanism is mostly independent of the conduct of monetary policy or the shocks do not play a major role for U.S. business cycles.

[24]The size of the shock depends on the standard deviation estimated in each of the two samples. As found in Table 4, the size of the shock in the two samples before 1979 is larger that the standard deviation estimated for the post-Volcker period.

[25]As discussed in Section 5.2, the data favors a specification which includes the forecast error associated with the inflation rate, $\eta_{\pi,t}$, as a non-fundamental shock. This implies that the inflation rate is predetermined as a function of the previous period's conditional expectation, $\pi_t = E_{t-1}(\pi_t) + \eta_{\pi,t}$. Equivalently, the inflation rate is not affected on impact.

**Risk-Premium Shock** The risk-premium shock represents a wedge between the policy rate set by the central bank and the return that households receive to hold their assets. As Figure 2 suggests, the shock has similar effects on the real economy regardless of the conduct of monetary policy. A (one standard deviation) negative shock increases consumption since the required rate of return on assets is lower. Also, the decrease in the cost of capital further stimulates economic activity due to larger investments by firms. However, the inflation response to the risk-premium shock depends on the conduct of monetary policy. When monetary policy is active, firms face a higher marginal cost that maps into inflationary pressures. When monetary policy is passive, agents observe a rise in the real interest rate and form self-fulfilling deflationary expectations due to the convergence of the economy to its long-run steady state. In this case, the risk-premium shock therefore dampens the inflation rate of the economy.

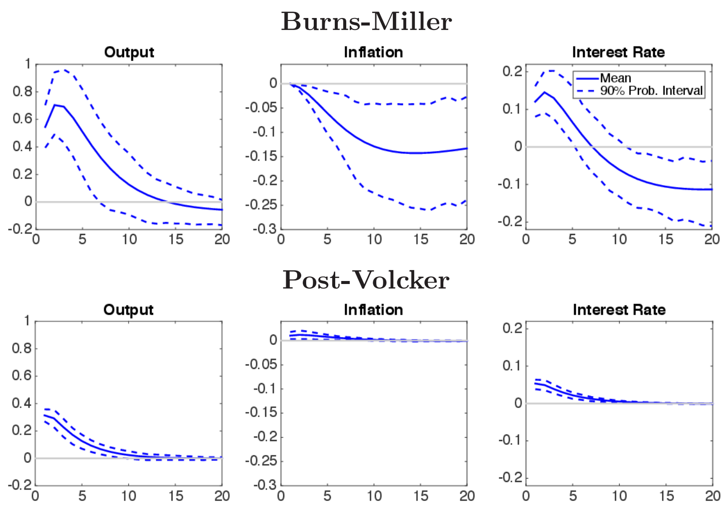


Figure 2: Mean impulse responses to a risk-premium shock are denoted by solid lines, while dashed lines represent the associated 90% probability intervals.

**Monetary Policy Shock** The bottom three panels of Figure 3 describe the predictions of a contractionary monetary policy shock under the active regime of the post-Volcker period. Output and inflation drop and revert to the steady state of the economy. When monetary policy is indeterminate, the responses to a contractionary monetary policy shock are reported in the top three panels. Economic activity is depressed. However, in line with the empirical findings of LS, the unexpected tightening of monetary policy is associated with a persistent inflationary effect. Agents form inflationary expectations due to the convergence of the economy back to its long-run. These expectations are then self-fulfilled and the contractionary monetary policy shock results into a persistent inflationary effect. Therefore, Figure 3 highlights the differences in the impact and the transmission of structural shocks such as an unexpected monetary policy tightening.

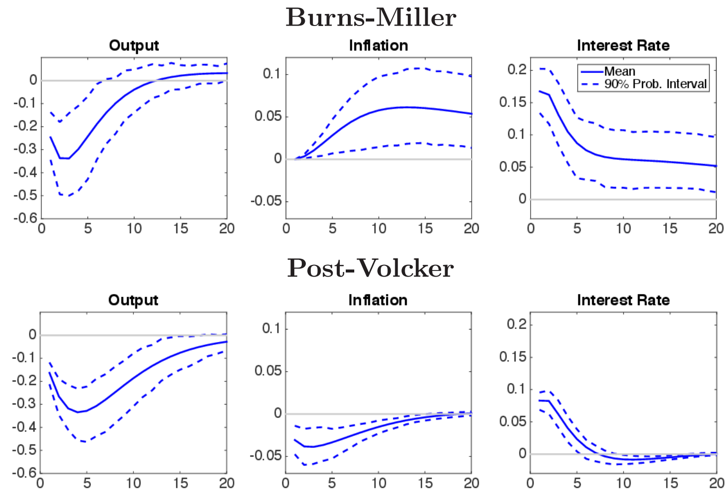


Figure 3: Mean impulse responses to a monetary policy shock are denoted by solid lines, while dashed lines represent the associated 90% probability intervals.

### 6.3 The History of U.S. Business Cycles

The interpretation of U.S. business cycle fluctuations relies on the conduct of monetary policy. I find that for the period prior to 1979, persistent technology shocks explain the upward trend in the inflation rate observed since the early 1960s. This result is in line with the observation of Fernald (2014a) according to which the U.S. economy experienced a period of exceptional growth in productivity since World War II until the oil crisis in 1973. Mark-up shocks account for the sudden inflationary episodes related to the oil price shocks during the early 1970s, but do not explain the persistent rise in the inflation rate. Sunspot shocks play a minor role to explain the high macroeconomic volatility observed before 1979. These findings indicate that the strong evidence of a passive monetary policy before 1979 lies in the persistence of the distinctive transmission mechanism of structural shocks rather than in the quantitative relevance of non-fundamental disturbances. Regarding the period after the Volcker disinflation, the results are in line with previous findings in the literature. The recessionary episodes in the early 1990s and the burst of dot com bubble are mostly explained by negative demand shocks, and mark-up shocks kept the inflation rate subdued relative to its target level during the 1990s.

#### 6.3.1 Martin and the Post-Korean War Period

I first focus on the post-Korean war period that starts in 1955 and during which William Martin has been the chairman of the Fed until 1969. Figure 8 plots the historical decomposition of the deviations of the inflation rate from its long-run for two alternative specifications.[26]

The top panel of Figure 4 plots the decomposition under indeterminacy that is favored by the data.[27] While sunspot shocks could have potentially contributed for the model to better match the high volatility in the inflation rate, the historical decomposition indicates that they played no quantitative role. The rise in inflation since the early 1960s is associated with a sequence of productivity shocks. In line with the analysis in Section 6.2 on the persistent inflationary effects induced by positive productivity shocks, the top panel indicates that the impact of each shock cumulated over time and explained the upward trend in the inflation rate.[28] As discussed below, this result is supported by the empirical evidence presented in Fernald (2014a) among others.

The bottom panel reports the decomposition that results by imposing equilibrium uniqueness as conducted in SW.[29] A comparison with the top panel also suggests that the assumption substantially affects the interpretation of the data. The upward trend in the inflation rate during the 1960s is erroneously attributed to mark-up shocks. However, the results in Section 6.1 reject the assumption, thus indicating that the correct interpretation relies on the top panel.

[26]The historical decomposition of output growth for the two sample periods prior to 1979 is provided in Appendix B and shows minor differences between the determinate and the indeterminate representation.

[27]To conduct the historical decompositions, I use the posterior means estimated for the pre-Volcker period for each of the two local maxima found during the estimation and that are reported in Table 3 and 4. Also, to simplify the analysis, I group the exogenous spending shock, the investment-specific shock and the risk-premium shock as "demand" shocks. Similarly, price and wage mark-up shocks are grouped as "mark-up" shocks.

[28]Monetary policy shocks had a minor impact that resulted into mildly deflationary pressures during the early 1960s. It is useful to recall that the historical decomposition cumulates the effect of a given shock on the inflation rate until a given date. Given the persistence of the monetary policy shocks under indeterminacy as described in Section 6.2, a monetary policy shock can be identified as the change in the contribution to explain the dynamics.

[29]Minor differences in the historical decomposition at a given year across the two panels are explained by differences in the contribution of the initial conditions for each representation.

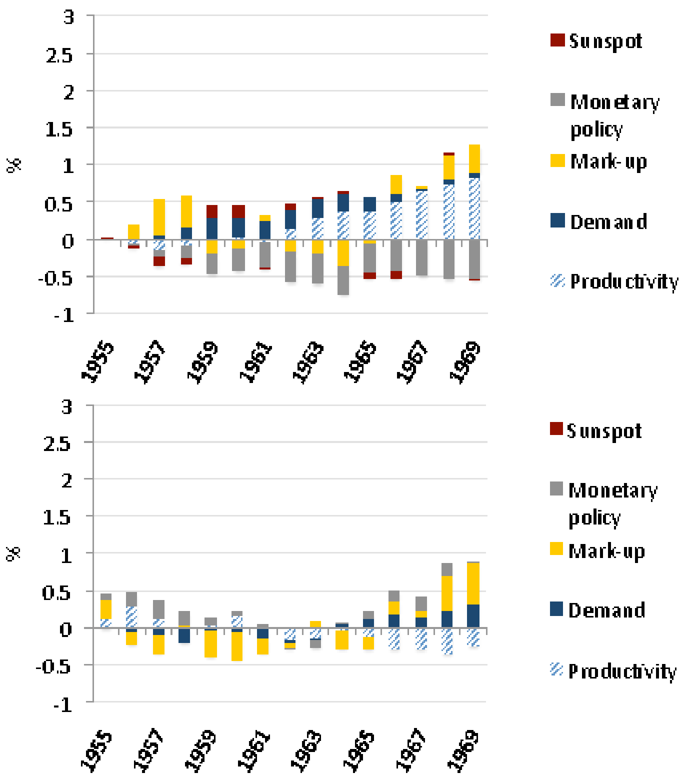


Figure 4: Sample 1955-1969. Historical decomposition of the inflation rate under indeterminacy (top) and determinacy (bottom) at quarterly rates.

The evidence that the U.S. economy experienced exceptional growth in productivity prior to the early 1970s is documented by Fernald (2014a) among others[30]. This literature points to a wave of technological innovations as the source of a rise in growth of productivity and therefore economic activity. In particular, when considering the quarterly time series for Total Factor Productivity produced by Fernald (2014b), the resulting (standardized) series is plotted in Figure 5 together with the smoothed productivity shocks estimated using the SW model. The comparison indicates that the estimation of the SW model successfully identifies the sequence of positive productivity shocks that the U.S. economy experienced starting from the early 1960s.[31] Importantly, in a passive monetary policy regime, productivity shocks generate persistent inflationary expectations that are consistent with the observed upward trend in inflation.

[30]Other work that supports this view is provided by Fernald (2014b), Gordon (2000), Davig and Wright (2000) and Field (2003).

[31]The correlation between the two sequences of productivity shocks is 0.74, suggesting that the model does remarkably well in extracting productivity shocks that are in line with Fernald (2014b).

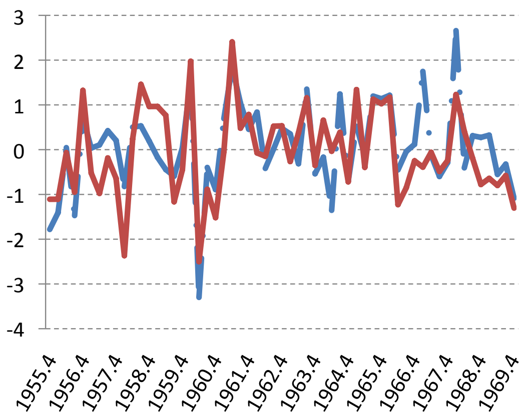


Figure 5: Sample 1955:4-1969:4. Quarterly (standardized) series of Total Factor Productivity from Fernald (2014a, solid line) and of the smoothed productivity shocks from SW model (dashed line) in percentages at quarterly rates.

### 6.3.2 The Burns and Miller Chairmanships

The second period begins with the chairmanship of Arthur Burns in 1970 and ends in 1979 with the conclusion of the chairmanship of William Miller. Figure 6 presents the historical decomposition of the inflation rate over this sample period according to alternative monetary policy regimes. The top panel presents the decomposition associated with indeterminacy as supported by the data, while the bottom panel is obtained by imposing the assumption that monetary policy successfully suppressed self-fulfilling expectations. As explained in Section 6.2, the conduct of a passive monetary policy is such that positive risk-premium shocks have a contractionary effect on the economy but also lead agents to form inflationary expectations that are self-fulfilling and persistent.[32] Hence, a combination of demand shocks and positive productivity shocks sustained the high inflation observed in the late 1970s, while the spike in 1979 is also attributed to mark-up shocks.[33] Even for this sample period, sunspot shocks have no quantitative relevance for U.S. business cycles. Conversely, the bottom panel shows that the assumption of an active monetary policy mistakenly attributes the fluctuations in the inflation rate exclusively to mark-up shocks.

[32] The drop in the inflation rate between 1969 in Figure 4 and 1970 in Figure 6 is due to a relatively mild recession that coincided with an attempt of the U.S. government to start closing the budget deficits of the Vietnam War. Hence, the decomposition attributes most of the drop to the initial condition since the economy is not at its steady state. However, as mentioned in Section 6.1.1, it is relevant to account for the two samples separately since the balanced growth path of the economy differs substantially.

[33] While Figure 6 generally refers to demand shocks, the break down for each demand shock shows that the contribution of the risk-premium shock is the most relevant as opposed to the government spending or investment-specific shocks.

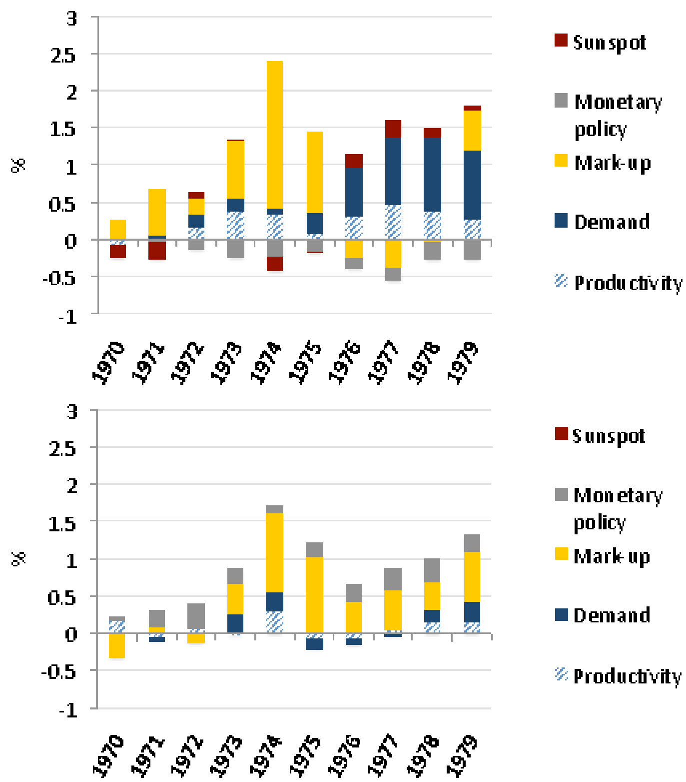


Figure 6: Sample 1970-1979. Historical decomposition of the deviation of the inflation rate from its steady state under indeterminacy (top) and determinacy (bottom) at quarterly rates.

### 6.3.3 The Post-Volcker Period

Finally, I focus on the post-Volcker period and Figure 7 reports the historical decomposition for the output gap (top panel) and the inflation rate (bottom panel). The decomposition is conducted under an active monetary policy as found in Section 6.1 for this sample period. The results are in line with those in SW. The economic contractions and below-target inflation rate of the early 1990s and 2000s are mostly explained by negative demand shocks, while mark-up shocks maintained the inflation rate subdued during the 1990s.

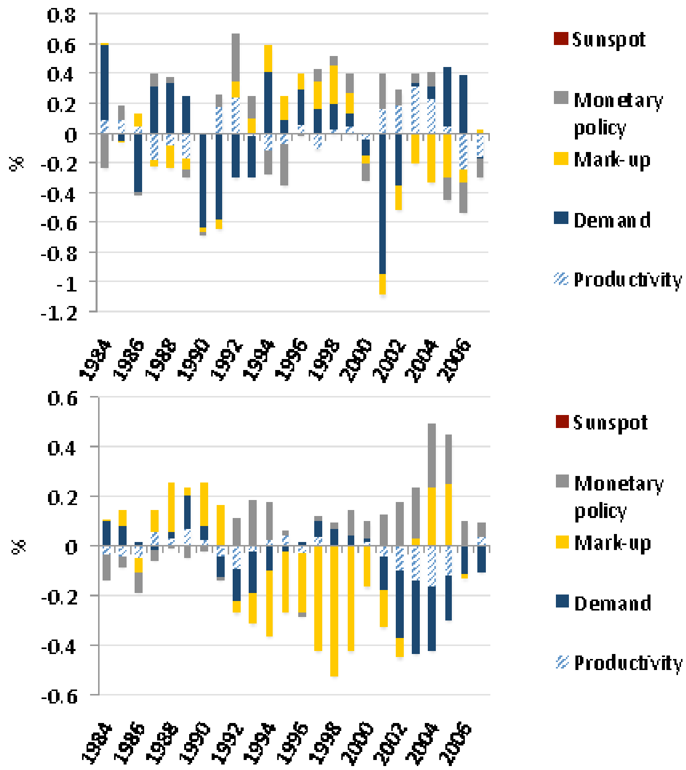


Figure 7: Post-Volcker sample. Historical decomposition of output gap (top) and inflation rate (bottom) at quarterly rates.

### 6.4 What Changed in the Early 1980s?

The work of Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) first documented the lower volatility of U.S. real GDP since the early-1980s. Extensive research has been conducted to provide explanations for the reduction in U.S. macroeconomic volatility. Using the SW model, I investigate the validity of two prominent theories that have been advocated to explain this empirical fact. The work by Sims and Zha (2006) suggests that the behavior of the data changed due to a decrease in the variance of the structural shocks since the Volcker disinflation. Primiceri (2005) finds some evidence that policy also changed, but the role played by structural disturbances is more relevant. According to this strand of the literature, the reduction in volatility of U.S. macroeconomic data is not related to monetary policy and it can therefore be considered as "good luck".

An alternative theory has been supported by the work of Clarida et al. (2000) and LS among others who find evidence of an active inflation targeting since the Volcker disinflation. The reduction in volatility can therefore be attributed to the "good policy" of the monetary authority.

The results in Section 6.1 support both theories. The comparison of the posterior estimates of the structural parameters in Table 3 indicates that the conduct of monetary policy changed toward a more aggressive stance in the post-Volcker period. Moreover, the estimates of the volatility of the shocks driving the economy dropped significantly since the early 1980s (Table 4). In this section, I show that, according to the SW model, *both* theories contribute to explain the reduction in U.S. macroeconomic volatility.

To provide an intuition for the approach that I adopt using the SW model, I first consider a conventional three-equation NK model such as in LS. The model is described by a dynamic IS curve

$$y_t = E_t\left(y_{t+1}\right) - \tau\left(R_t - E_t\left(\pi_{t+1}\right)\right) + z_{d,t},$$

a NK Phillips Curve

$$\pi_t = E_t\left(\pi_{t+1}\right) + \kappa\left(y_t - z_{s,t}\right),$$

and a monetary policy reaction function

$$R_t = \phi_\pi \pi_t + \varepsilon_{R,t},$$

where $y_t$ represents the deviation of output from its trend and the demand shock, $z_{d,t}$, and supply shock, $z_{s,t}$, are autoregressive processes of the form

$$z_{d,t} = \rho_d z_{d,t-1} + \varepsilon_{d,t} \qquad\qquad z_{s,t} = \rho_s z_{s,t-1} + \varepsilon_{s,t}.$$

To test alternative theories, I estimate different model specifications by imposing restrictions on sets of parameters and volatilities. In Model 1, "Policy and Shocks", I constrain the private sector parameters, $\{\tau, \kappa\}$, to be the same across the period from 1955 to 1979 and the period from 1984 to 2007. I also allow the policy parameter, $\phi_\pi$, the variances of the shocks, $\{\sigma_d, \sigma_s\}$, and the autoregressive coefficients, $\{\rho_d, \rho_s\}$, to vary across the two periods. This specification considers a combination of "good luck" and "good policy" to explain the data. Relative to Model 1, I then consider Model 2, "Shocks only", by further restricting the policy parameter, $\phi_\pi$, thus considering the "good luck" view. Conversely, consistent with the "good policy" theory, Model 3, "Policy only", allows for the policy parameter to vary across sub-periods, while constraining all the other structural parameters and variances to be constant. Following the intuition provided with the conventional three-equation NK model, I apply the same approach to estimate alternative model specifications of the SW model and test for the validity of the "good luck" and/or "good policy" theory in the data.

Table 8 reports the marginal data densities obtained for the estimation of each of the three models. The posterior model probabilities are computed as pairwise comparisons relative to

| | Log data density | Posterior model prob | |
|---|---|---|---|
| Policy and shocks | -986.85 | 100% | 100% |
| Shocks only | -994.51 | 0% | - |
| Policy only | -1021.08 | - | 0% |

Table 8: The table reports the marginal data densities for the three alternative specifications and the pairwise posterior model probabilities relative to Model 1, Policy and Shocks.

Model 1, Policy and Shocks, and indicate that, based on the SW model, a combination of both good luck and good policy is the explanation for the observed reduction in the volatility since the mid-1980s. Also, in line with the findings of Primiceri (2005), Model 2, Shocks only, has a more relevant role rather than the theory based exclusively on the change of monetary policy to an active stance, Model 3 Policy only.

Focusing on the estimation of Model 1, Policy and Shocks, Table 9 reports the posterior estimates of the constrained parameters across the two sub-samples. As expected, the posterior distribution of the model parameters are in line with those estimated for the two samples separately and reported in Section 6.1.

| Coefficient | Description | Mean | [ 5 , 95 ] |
|---|---|---|---|
| $\phi$ | Adjustment cost | 6.59 | [4.75,8.48] |
| $\sigma_c$ | IES | 1.44 | [1.25,1.63] |
| $h$ | Habit Persistence | 0.62 | [0.51,0.73] |
| $\sigma_l$ | Labor supply elasticity | 2.14 | [1.37,2.91] |
| $\xi_w$ | Wage stickiness | 0.84 | [0.79,0.89] |
| $\xi_p$ | Price Stickiness | 0.77 | [0.70,0.83] |
| $\iota_w$ | Wage Indexation | 0.40 | [0.24,0.56] |
| $\iota_p$ | Price Indexation | 0.18 | [0.06,0.30] |
| $\psi$ | Capacity utiliz. elasticity | 0.68 | [0.55,0.81] |
| $\Phi$ | Share of fixed costs | 1.63 | [1.50,1.75] |
| $\alpha$ | Share of capital | 0.22 | [0.19,0.25] |
| $\bar{\pi}$ | S.S. inflation rate (quart.) | 0.60 | [0.48,0.71] |
| $100(\beta^{-1}-1)$ | Discount factor | 0.10 | [0.04,0.16] |
| $\bar{l}$ | S.S. hours worked | 0.67 | [-0.29,1.55] |
| $\bar{\gamma}$ | Trend growth rate (quart.) | 0.42 | [0.39,0.45] |

Table 9: The table reports the posterior estimates of the constrained structural parameters.

Table 10 and 11 highlight substantial differences in the posterior estimates for the policy parameters and the exogenous processes between the two periods. Monetary policy acted more systematically to stabilize inflation. Consistent with the findings of Sims and Zha (2006) among others, the magnitude of the volatility of the shocks is significantly reduced in the post-Volcker period.

| | | Pre-Volcker (55:4 - 79:2) | | Post-Volcker (84:1 - 07:3) | |
|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $r_\pi$ | Taylor rule inflation | 0.85 | [0.73,0.97] | 1.80 | [1.37,2.18] |
| $r_y$ | Taylor rule output gap | 0.15 | [0.09,0.21] | 0.05 | [0.02,0.10] |
| $r_{\Delta y}$ | Taylor rule $\Delta$(output gap) | 0.17 | [0.12,0.22] | 0.17 | [0.12,0.21] |
| $\rho$ | Taylor rule smoothing | 0.86 | [0.80,0.91] | 0.84 | [0.80,0.88] |

Table 10: The table reports the posterior estimates of policy parameters for the pre- and post-Volcker period.

| | | Pre-Volcker (55:4 - 79:2) | | Post-Volcker (84:1 - 07:3) | |
|---|---|---|---|---|---|
| Coefficient | Description | Mean | [ 5 , 95 ] | Mean | [ 5 , 95 ] |
| $\sigma_a$ | Technology shock | 0.54 | [0.47,0.60] | 0.36 | [0.31,0.40] |
| $\sigma_b$ | Risk premium shock | 0.14 | [0.08,0.19] | 0.15 | [0.08,0.21] |
| $\sigma_g$ | Government sp. shock | 0.53 | [0.46,0.60] | 0.41 | [0.36,0.46] |
| $\sigma_I$ | Investment-specific shock | 0.45 | [0.35,0.56] | 0.30 | [0.23,0.37] |
| $\sigma_r$ | Monetary policy shock | 0.17 | [0.15,0.20] | 0.12 | [0.10,0.14] |
| $\sigma_p$ | Price mark-up shock | 0.30 | [0.25,0.34] | 0.09 | [0.07,0.11] |
| $\sigma_w$ | Wage mark-up shock | 0.26 | [0.22,0.30] | 0.31 | [0.25,0.37] |
| $\sigma_\nu$ | Sunspot shock | 0.06 | [0.01,0.11] | - | - |
| $\rho_a$ | Persistence technology | 0.97 | [0.96,0.98] | 0.93 | [0.89,0.96] |
| $\rho_b$ | Persistence risk premium | 0.75 | [0.55,0.93] | 0.38 | [0.05,0.71] |
| $\rho_g$ | Persistence government sp. | 0.90 | [0.86,0.95] | 0.97 | [0.95,0.98] |
| $\rho_I$ | Persistence investment-specific | 0.68 | [0.55,0.81] | 0.74 | [0.62,0.86] |
| $\rho_r$ | Persistence monetary policy | 0.35 | [0.20,0.51] | 0.32 | [0.19,0.45] |
| $\rho_p$ | Persistence price mark-up | 0.24 | [0.04,0.42] | 0.82 | [0.73,0.92] |
| $\rho_w$ | Persistence wage mark-up | 0.34 | [0.12,0.55] | 0.69 | [0.50,0.88] |
| $\mu_p$ | MA price mark-up | 0.77 | [0.64,0.92] | 0.63 | [0.44,0.83] |
| $\mu_w$ | MA wage mark-up | 0.38 | [0.21,0.57] | 0.56 | [0.32,0.80] |
| $\rho_{ga}$ | $Cov(\sigma_a, \sigma_g)$ | 0.62 | [0.46,0.76] | 0.40 | [0.22,0.57] |

Table 11: The table reports the posterior estimates of parameters associated with the exogenous shocks for the pre- and post-Volcker period.

## 7 Conclusions

The paper studies the relevance of the interactions between monetary policy and the formation of expectations for U.S. business cycle fluctuations during the post-war period. I argue that a quantitative assessment of the mechanisms that rationalize the behavior of the data requires the adoption of a rich dynamic and stochastic structure such as the SW model. By implementing the methodology of Bianchi and Nicolò (2017), this paper constitutes, to the best of my knowledge, the first study that quantitatively investigates the role of self-fulfilling expectations and non-fundamental disturbances for the macroeconomic instability observed in the United States prior to 1979 in the context of a medium-scale model.

The data strongly supports the evidence of a passive monetary policy before 1979, even when accounting for richer propagation mechanisms and additional structural shocks. According to this monetary regime, the transmission of structural shocks is altered and crucially depends on the de-anchoring of expectations that instead are self-fulfilling.

The quantitative relevance of the role of self-fulfilling expectations and non-fundamental disturbances provides an explanation for U.S. business cycle that differs from previous studies such as SW in which these mechanisms are excluded *a priori*. While in the latter the run-up in inflation from the early 1960s to 1979 is attributed exclusively to mark-up shocks, the transmission mechanism based on self-fulfilling expectations provides an alternative explanation. Productivity shocks generated economic activity and self-fulfilling inflationary pressures that account for the rise in inflation in the 1960s. Mark-up shocks have quantitative importance to explain the sudden rise in inflation during the oil crisis of the 1970s. The high volatility before 1979 is explained by large structural shocks, while non-fundamental sunspot shocks play no quantitative role.

Extensions of this work would explore the possibility of accounting not only for dynamic indeterminacy, but also for static indeterminacy (i.e. multiplicity of steady states). Based on these cointegrating properties of the data (Beyer and Farmer, 2007b), Farmer and Platonov (2016) develop a micro-founded model that accounts for the possibility of observing multiple steady-state unemployment rates.[34] The three-equations version of the model corresponds to the structural representation studied in Farmer (2012). The model is equivalent to the conventional three-equation NK model in which the NK Phillips curve is replaced by a 'belief function' that describes how agents form expectations about future nominal income growth. In Farmer and Nicolò (2017), we show that the reduced-form representation corresponds

[34] Beyer and Farmer (2007b) study the low frequency comovements in unemployment, inflation and the federal funds rate and find that the data is well described by cointegrating relationships. This evidence raises doubts about the validity of the natural rate hypothesis on which conventional NK models such as SW rely (i.e. the assumption that the long-run unemployment rate is independent of monetary and fiscal policies).

to a cointegrated Vector Error Correction Model (VECM) and the model outperforms the conventional three-equation NK model in fitting the data before and after 1979.

An interesting avenue of research extends the proposed alternative framework to a medium-scale model that also displays multiplicity of steady states and therefore maps into a VECM in reduced-form. The purpose would therefore be to study whether the cointegrating properties of the proposed model would better explain the data in the post-war period relative to a conventional NK model that displays self-stabilizing properties around the unique steady state.

## References


Alejandro Justiniano, G. E. P. and Tambalotti, A. (2010). Investment Shocks and Business Cycles. *Journal of Monetary Economics*, 57(March):132–145.

Alejandro Justiniano, G. E. P. and Tambalotti, A. (2011). Investment Shocks and the Relative Price of Investment. *Review of Economic Dynamics*, 14(1):101–121.

Anderson, G. and Moore, G. (1985). A linear algebraic procedure for solving linear perfect foresight models. *Economic Letters*, 17.

Arias, J. E., Ascari, G., Branzoli, N., and Castelnuovo, E. (2017). Monetary policy, trend inflation and the Great Moderation: An alternative interpretation - Comment. *Working paper*.

Bernanke, B. (2015). The taylor rule: a benchmark for monetary policy? http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/28-taylor-rule-monetary-policy.

Bernanke, B. S. and Blinder, A. (1992). The federal funds rate and the channels of monetary transmission. *American Economic Review*, 82:901–921.

Bernanke, B. S. and Mihov, I. (1998). Measuring monetary policy. *Quarterly Journal of Economics*, 113(3):869–902.

Beyer, A. and Farmer, R. E. (2007a). Testing for indeterminacy: An application to U.S. monetary policy: Comment. *American Economic Review*, 97(1):524–529.

Beyer, A. and Farmer, R. E. A. (2007b). Natural rate doubts. *Journal of Economic Dynamics and Control*, 31(121):797–825.

Bhattarai, S., Lee, J. W., and Park, W. Y. (2016). Policy regimes, policy shifts, and u.s. business cycles. *Review of Economics and Statistics*, 98:968–983.

Bianchi, F. (2013). Regime switches, agents' beliefs and post-wold-war ii u.s. macroeconomics dynamics. *Review of Economic Studies*. In Press.

Bianchi, F. and Ilut, C. (2017). Monetary/fiscal policy mix and agents' beliefs. *Review of Economic Dynamics*. forthcoming.

Bianchi, F. and Nicolò, G. (2017). A generalized approach to indeterminacy in linear rational expectations models. NBER Working Paper No. 23521.

Blanchard, O. J. and Kahn, C. M. (1980). The solution of linear difference models under rational expectations. *Econometrica*, 48(July):1305–1311.

Boivin, J. and Giannoni, M. P. (2006). Has monetary policy become more effective?

Christiano, L., Eichenbaum, M., and Evans, C. (2005). Nominal rigidities and the dynamics effects of a shock to monetary policy. *Journal of Political Economy*, 113:1–45.

Clarida, R., Galí, J., and Gertler, M. (2000). Monetary policy rules and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics*, CXV:147–180.

Coibon, O. and Gorodnichenko, Y. (2011). Monetary policy, trend inflation, and the Great Moderation: An Alternative Interpretation. *American Economic Review*, 101(1):341–370.

Davig, P. and Wright, G. (2000). General purpose technologies and productivity surges: Historical reflections on the future of the ict revolution. In David, P. A. and Thomas, M., editors, *The Economic Future in Historical Perspective*. Oxford University Press.

Del Negro, M. and Eusepi, S. (2011). Fitting Observed Inflation Expectations. *Journal of Economic Dynamics and Control*, 35(12):2105–2131.

Del Negro, M. and Schorfheide, F. (2009). Monetary Policy Analysis with Potentially Misspecified Models. *American Economic Review*, 99(4):1415–50.

Del Negro, M., Schorfheide, F., Smets, F., and Wouters, R. (2007). On the Fit of New Keynesian Models. *Journal of Business and Economics Statistics*, 25:123–143.

Doko Tchatoka, F., Groshenny, N., Haque, Q., and Weder, M. (2017). Monetary policy and indeterminacy after the 2001 slump. *Journal of Economic Dynamics and Control*, 82:83–95.

Farmer, R. E., Khramov, V., and Nicolò, G. (2015). Solving and estimating indeterminate DSGE models. *Journal of Economic Dynamics and Control*, 54:17–36.

Farmer, R. E. A. (2012). Animal spirits, persistent unemployment and the belief function. In Frydman, R. and Phelps, E. S., editors, *Rethinking Expectations: The Way Forward for Macroeconomics*, chapter 5, pages 251–276. Princeton University Press, Princeton, NJ.

Farmer, R. E. A. and Guo, J. T. (1994). Real business cycles and the animal spirits hypothesis. *Journal of Economic Theory*, 63:42–73.

Farmer, R. E. A. and Guo, J.-T. (1995). The econometrics of indeterminacy. *Carnegie Rochester Series on Public Policy*, 43:225–273.

Farmer, R. E. A. and Nicolò, G. (2017). Keynesian economics without the phillips curve. *NBER Working Paper No. 22837*.

Farmer, R. E. A. and Platonov, K. (2016). Animal spirits in a monetary model. *NBER Working Paper No. 22136*.

Fernald, J. (2014a). Productivity and potential output before, during, and after the great recession. *NBER Working Paper No. 20248*.

Fernald, J. (2014b). A quarterly, utilization-adjusted series on total factor productivity. *Federal Reserve Bank of San Francisco*.

Fernandez-Villaverde, J., Guerron-Quintana, P., and Rubio-Ramirez, J. (2010). Reading the recent monetary history of the united states, 1959-2007. *Federal Reserve Bank of St. Louis, Review*, 92(4).

Field, A. J. (2003). The most technologically progressive decade of the century. *American Economic Review*, 93(4):1399–1413.

Galí, J. and Gertler, M. (1999). Inflation dynamics: A structural econometric analysis. *Journal of Monetary Economics*.

Geweke, J. (1999). Using simulation methods for bayesian econometric models: Inference, development, and communication. *Econometric Reviews*, 18:1–73.

Gordon, R. J. (2000). Does the "new economy" measure up to the great inventions of the past? *Journal of Economic Perspectives*, 4(14):49–74.

Justiniano, A. and Primiceri, G. E. (2008). The Time Varying Volatility of Macroeconomic Fluctuations. *American Economic Review*, 98(3):604–641.

Kim, C.-J. and Nelson, C. R. (1999). Has the US economy become more stable? a Bayesian approach based on a Markov-Switching model of the business cycle. *Review of Economics and Statistics*, 81:608–16.

Lubik, T. A. and Schorfheide, F. (2003). Computing sunspot equilibria in linear rational expectations models. *Journal of Economic Dynamics and Control*, 28(2):273–285.

Lubik, T. A. and Schorfheide, F. (2004). Testing for indeterminacy: An application to U.S. monetary policy. *American Economic Review*, 94:190–219.

McConnell, M. M. and Perez-Quiros, G. (2000). Output fluctuations in the United States: What has changed since the early 1980s? *American Economic Review*, 90:1464–76.

Orphanides, A. (2002). Monetary policy rules and the great inflation. *American Economic Review, Papers and Proceedings*, 92(2):115–120.

Primiceri, G. E. (2005). Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies*, 72:821–852.

Primiceri, G. E. (2006). Why inflation rose and fell: Policymakers' beliefs and us postwar stabilization policy. *The Quarterly Journal of Economics*, 121(August):867–901.

Sims, C. A. (2001). Solving linear rational expectations models. *Journal of Computational Economics*, 20(1-2):1–20.

Sims, C. A. and Zha, T. (2006). Were there regime switches in us monetary policy? *American Economic Review*, 96(1):54–81.

Smets, F. and Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, 1(5):1123–1175.

Smets, F. and Wouters, R. (2007). Shocks and frictions in U.S. business cycles: A bayesian DSGE approach. *American Economic Review*, 97(3):586–606.

Stock, J. H. and Watson, M. W. (2003). Has the business cycles changed? evidence and explanations. Monetary Policy and Uncertainty: Adapting to a Changing Economy, Federal Reserve Bank of Kansas City Symposium, Jackson Hole, Wyoming, August 28-30.

Taylor, J. B. (2012). *The great divergence. In: Koening, E., R., Kahn, G. (Eds.). The Taylor Rule and the Transformation of Monetary Policy.* Hoover Institution, Stanford.

Uhlig, H. (1999). A toolkit for analyzing nonlinear dynamic stochastic models easily. In Marimon, R. and Scott, A., editors, *Computational Methods for the Study of Dynamic Economies*, pages 30–61. Oxford University Press, Oxford, England.

Yasuo Hirose, T. K. and Zandweghe, W. V. (2017). Monetary policy and macroeconomic stability revisited. *Federal Reserve Bank of Kansas City, Research Working Paper*, 17-01.

# Appendix A

Appendix A reports the prior distributions of the structural parameters and volatility of the shocks used for the estimation of the SW model.

| Coefficient | Description | Distr. | Mean | Std. Dev |
|---|---|---|---|---|
| $\phi$ | Adjustment cost | Normal | 4.00 | 1.50 |
| $\sigma_c$ | IES | Normal | 1.50 | 0.37 |
| $h$ | Habit Persistence | Beta | 0.70 | 0.10 |
| $\sigma_l$ | Labor supply elasticity | Normal | 2.00 | 0.75 |
| $\xi_w$ | Wage stickiness | Beta | 0.50 | 0.10 |
| $\xi_p$ | Price Stickiness | Beta | 0.50 | 0.10 |
| $\iota_w$ | Wage Indexation | Beta | 0.50 | 0.15 |
| $\iota_p$ | Price Indexation | Beta | 0.50 | 0.15 |
| $\psi$ | Capacity utilization elasticity | Beta | 0.50 | 0.15 |
| $\Phi$ | Share of fixed costs | Normal | 1.25 | 0.12 |
| $\alpha$ | Share of capital | Normal | 0.30 | 0.05 |
| $\bar{\pi}$ | S.S. inflation rate (quart.) | Gamma | 0.62 | 0.10 |
| $100(\beta^{-1}-1)$ | Discount factor | Gamma | 0.25 | 0.10 |
| $\bar{l}$ | S.S. hours worked | Normal | 0.00 | 2.00 |
| $\bar{\gamma}$ | Trend growth rate | Normal | 0.40 | 0.10 |
| $r_\pi$ | Taylor rule inflation | Normal | ***1.00*** | ***0.35*** |
| $r_y$ | Taylor rule output gap | Normal | 0.12 | 0.05 |
| $r_{\Delta y}$ | Taylor rule $\Delta$(output gap) | Normal | 0.12 | 0.05 |
| $\rho$ | Taylor rule smoothing | Beta | 0.75 | 0.10 |

Table 12: The table reports the prior distributions for the structural parameters of the model.

| Coefficient | Description | Distr. | Mean | Std. Dev |
|---|---|---|---|---|
| $\sigma_a$ | Technology shock | Invgamma | 0.10 | 2.00 |
| $\sigma_b$ | Risk premium shock | Invgamma | 0.10 | 2.00 |
| $\sigma_g$ | Government sp. shock | Invgamma | 0.10 | 2.00 |
| $\sigma_I$ | Investment-specific shock | Invgamma | 0.10 | 2.00 |
| $\sigma_r$ | Monetary policy shock | Invgamma | 0.10 | 2.00 |
| $\sigma_p$ | Price mark-up shock | Invgamma | 0.10 | 2.00 |
| $\sigma_w$ | Wage mark-up shock | Invgamma | 0.10 | 2.00 |
| $\sigma_\nu$ | Sunspot shock | Uniform[0,1] | 0.50 | 0.29 |
| $\rho_a$ | Persistence technology | Beta | 0.50 | 0.20 |
| $\rho_b$ | Persistence risk premium | Beta | 0.50 | 0.20 |
| $\rho_g$ | Persistence government sp. | Beta | 0.50 | 0.20 |
| $\rho_I$ | Persistence investment-specific | Beta | 0.50 | 0.20 |
| $\rho_r$ | Persistence monetary policy | Beta | 0.50 | 0.20 |
| $\rho_p$ | Persistence price mark-up | Beta | 0.50 | 0.20 |
| $\rho_w$ | Persistence wage mark-up | Beta | 0.50 | 0.20 |
| $\mu_p$ | Mov. Avg. term, price mark-up | Beta | 0.50 | 0.20 |
| $\mu_w$ | Mov. Avg. term, wage mark-up | Beta | 0.50 | 0.20 |
| $\rho_{ga}$ | $Cov(\sigma_a, \sigma_g)$ | Normal | 0.50 | 0.25 |
| $\rho_{\nu p}$ | $Corr(\sigma_\nu, \sigma_p)$ | Uniform[-1,1] | 0 | 0.57 |

Table 13: The table reports the prior distributions for the exogenous processes of the model.

## Appendix B

Figure 8 plots the historical decomposition of the output gap for two alternative specifications. The panel at the top decomposes the output gap for the case of a failure to stabilize the economy, as shown in Section 6.1. The bottom panel reports the decomposition that results from the assumption of equilibrium uniqueness as conducted in SW. The two plots indicate minor differences and attribute the recessions of the late 1950s to demand shocks and the contractions of the early 1970s to a combination of mark-up and demand shocks. Also, non-fundamental disturbances had almost no effect on the observed fluctuations in the output gap. The similarity of the decomposition should not come as a surprise. Indeed, the analysis conducted in Section 6.2 shows that the transmission of the structural shocks on the output gap is roughly invariant to the of monetary policy stance, given that the differences in the magnitudes are due to the larger size of the estimated standard deviations of the shocks for the pre-Volcker period.

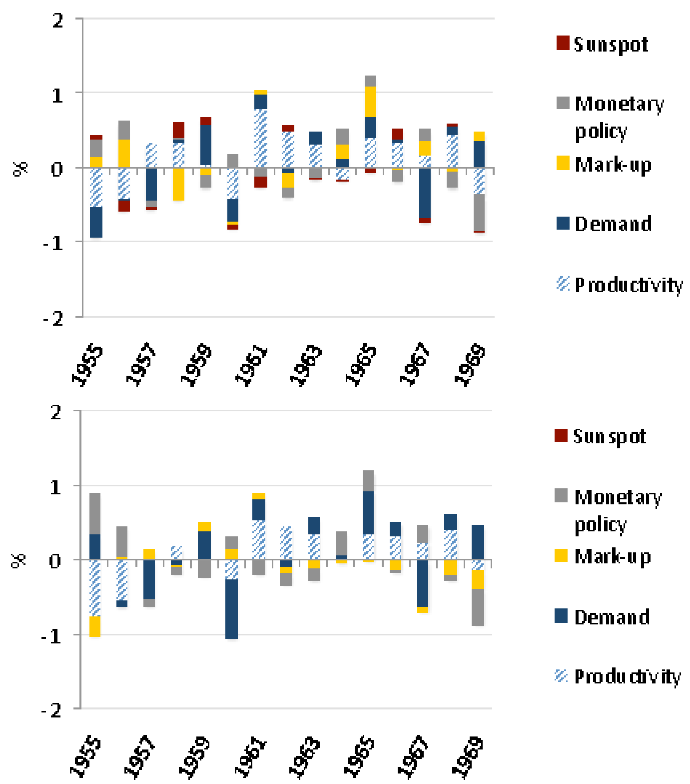


Figure 8: Sample 1955-1969. Historical decomposition of the output gap under indeterminacy (top) and determinacy (bottom).

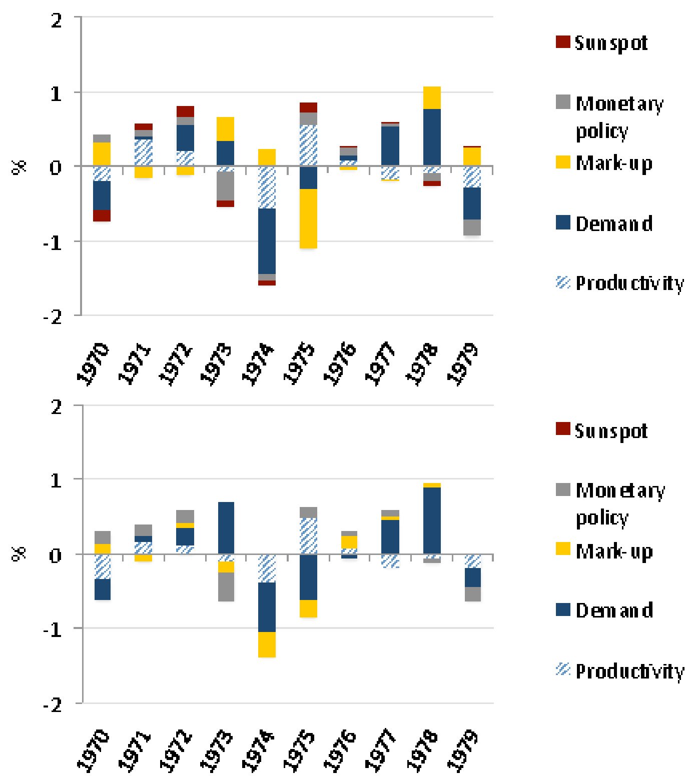


Figure 9: Sample 1970-1979. Historical decomposition of the output gap under indeterminacy (top) and determinacy (bottom).