Policy Preferences and Policymakers' Beliefs: The Great Inflation

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Preferences and Beliefs: The Great Inflation

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Abstract

The literature has proposed two potential channels through which monetary policy played a role in the Great Inflation in the United States. One approach posits that the Federal Reserve held misperceptions about the economy. An alternative explanation contends that policymakers shifted preferences from an output gap stabilization goal toward inflation stabilization after 1979. This paper develops a medium-scale macroeconomic model that incorporates real-time *learning* by policymakers as well as a (potential) shift in policymakers' preferences. The empirical results show that combining both views—distorted policymakers' beliefs about the persistence of inflation and the inflation-output gap trade-off, accompanied by a stronger preference for inflation stabilization after 1979—illustrates the role played by monetary policy in propagating and ending the Great Inflation.

Keywords: Great Inflation, policy preferences, policymakers beliefs, constant gain learning.

JEL classification: C11, D83,E31, E50, E52, E58.

Introduction

The rise and subsequent fall of inflation in the United States during the 1970s and 1980s—the "Great Inflation"—has been the subject of extensive research.[1] One promising line of research (see Orphanides, 2001; Sargent, 1999; and Primiceri, 2006) presupposes that policymakers were learning about the structure of the economy in real time. Their learning mechanism led them to believe in an overly optimistic view of potential output and,—while trying to estimate the coefficients of a statistical "Phillips curve"—in an exploitable trade-off.[2] Cecchetti et al. (2007) argue, however, that policymaker's learning alone cannot fully explain the rapid disinflation process experienced by the United States in the 1980s. Cecchetti et al. (2007) and Dennis (2006) propose that a key factor in explaining the Great Inflation was a change in preferences toward output gap stabilization by officials at the Federal Reserve. This paper's contribution is to combine these two hypotheses—policymakers' learning and a shift in policymakers' preferences—and provide evidence of their relative importance in the rise and fall of inflation in the United States during the 1970s and 1980s with regard to the appointment of Paul Volcker as chairman of the Federal Reserve.

The first hypothesis is that the Federal Reserve, uncertain about the structural features of the economy, would use econometric models to infer the current state and the laws of motion for the economy (Sargent [1999]; Primiceri [2006]; Orphanides [2001]). Primiceri shows that such an adaptive learning process, in which policymakers update their parameters over time with a constant gain learning rule, might lead to *beliefs* that could induce policymakers to create excessive inflation. These beliefs led policymakers to underestimate the persistence of inflation and overestimate the sacrifice cost of disinflation (Romer and Romer [2002]; Cogley and Sargent [2005]; Carboni and Ellison, [2009]; Pruitt, [2010]). The findings of Sargent, Williams and Zha (2006); Romer and Romer (2002); Sargent (1999); and Primiceri (2006) show that misperceptions about the standard features of the U.S. economy (such as (i) how to measure the natural rate of unemployment or (ii) the characteristics of a statistical Phillips curve) were important factors in the Great Inflation. Primiceri concludes that a change in the perceived inflation-unemployment trade-off was what brought an end to the Great Inflation.

The second hypothesis proposes that during the late 1960s and throughout the 1970s monetary policymakers preferred to stabilize output, whereas after 1979 they preferred to stabilize inflation (Bernanke [2004]). De Long (1997) argues that between the late 1960s and the late 1970s, with the Great Depression fresh in their memories, Federal Reserve officials "lacked the mandate to fight inflation by inducing a significant recession" (De Long [1997] p. 273).

This paper analyzes the Great Inflation in a medium-scale macroeconomic model that embeds both hypotheses: changing policymakers' beliefs about the state of the economy through adaptive learning and a possible change in policymakers' preferences. The relative importance of these two channels is an empirical question, so I estimate a New Keynesian dynamic stochastic general equilibrium (DSGE) model—known to provide a good empirical fit to the U.S. data that includes wage and price stickiness—as the "true model" of the economy. Following Primiceri (2006), I assume that policymakers, given their preferences, optimally form policy subject to their perceived model for the economy. It follows that policymakers have imperfect information about the economy and use historical data to learn the parameters over time, updating their beliefs through constant gain (or "perpetual") learning.

One contribution of this paper is its use of likelihood-based Bayesian methods to estimate the weights of the central bank's loss function along with a structural model for the U.S. economy. I estimate the weights of the loss function for the pre- and post-1979 periods (1979 was the year that Paul Volcker was appointed chairman of the Board of Governors of the Federal Reserve System). The change in *preferences* (or lack thereof) between the two periods is identified by the change in the weights of the central bank loss function. This approach builds on the work of Dennis (2006) and Salemi (1995), who use maximum likelihood methods to estimate parameters in the objective function jointly with parameters in the optimizing constraint. They conclude that the appointment of a different chairman of the Federal Reserve is consistent with policy regime changes or changes in policy preferences.[3]

The empirical results of this paper show that policymakers' beliefs, in addition to a change in their preferences at the beginning of the disinflation era, played key roles in propagating and ending the Great Inflation in the United States. Policymakers in the estimated model did not react strongly enough to inflation during the early 1970s because they perceived a downward-biased estimate of the persistence of inflation that would revert to its mean value at any time; in the mid-1970s they made an upward revision of this parameter toward its true value.[4] Moreover, policymakers' perceived an unfavorable trade-off between the output gap and inflation in the mid-1970s. Thus, policymakers did not fight inflation because they did not believe that it would work at a reasonable cost. The perceived trade-off between the output gap and inflation did not improve until the 1980s when an active inflation stabilization regime was installed. Active inflation stabilization regimes lead to improvements in the inflation-output gap trade-off (i.e., Bianchi and Melosi [2012]).

This paper also provides evidence of a shift in preferences by central bankers ascribed to output gap stabilization relative to inflation stabilization after 1979. In this model the central bank's objective is to stabilize the output gap in the pre-Volcker period; however, after Volcker's appointment the relative weight assigned by central bankers to output gap stabilization approaches zero. This shift in preferences after 1979 helps to explain the disinflation process that started after Volcker's appointment as chairman of the Federal Reserve.

The Model

The empirical model is a standard New Keynesian model in the spirit of Erceg, Henderson, and Levin (2000), Woodford (2003).[5] This model includes internal habit persistence, wage stickiness, and inflation inertia, which have been proven to improve the empirical properties of the model, giving more realism to the transmission mechanisms.[6] This standard simple framework has been pervasive in the monetary policy literature and is the foundation of large-scale models that are often used to characterize the U.S. economy (e.g., Christiano, Eichenbaum, and Evans [2005]; Smets and Wouters [2007]).

This model incorporates optimal wage setting in a DSGE context, as well as a measure of wage inflation in the policymakers' loss function. This segment of the model is important because the behavior of wages and wage inflation provides information about the rate of core inflation during the late 1960s and most of the 1970s, as in De Long (1997). He suggests that while the "magnitude of the inflation control problem" changed between the late 1960s (when policymakers realized the problem) and the beginning of Volcker's disinflation, the "qualitative nature of the problem did not." Paul Volcker at the end of the 1970s and Arthur Burns at the beginning of the 1970s had to confront the same issue of how to slow wage inflation, and therefore, the core of inflation.

The economy can be represented by the following system of equations:

$$\widetilde{x}_t = E_t\widetilde{x}_{t+1} - \varphi^{-1}[i_t - E_t\pi_{t+1} - r_t^n], \tag{1}$$

where

$$\widetilde{x}_t \equiv (x_t - \eta x_{t-1}) - \beta\eta E_t(x_{t+1} - \eta x_t). \tag{2}$$

and $\varphi \equiv [(1-\eta\beta)\sigma]^{-1}$.[7] The log-linearized Euler equation (1) includes x_t that represents the output gap, π_t is price inflation, and i_t is the nominal interest rate set by the central bank (determined within the model), and E_t represents rational expectations.The sensitivity of output to changes in the interest rate is measured by φ^{-1}.

The supply-side model is given by the following equations:

$$\pi_t^w - \gamma_w\pi_{t-1} = \xi_w[\omega_w x_t + \varphi\widetilde{x}_t] + \xi_\omega(w_t^n - w_t) + \beta E_t(\pi_{t+1}^w - \gamma_w\pi_t) + u_t^w \tag{3}$$

$$\pi_t - \gamma_p\pi_{t-1} = \kappa_p x_t + \xi_p(w_t - w_t^n) + \beta E_t(\pi_{t+1} - \gamma_p\pi_t) + u_t^p, \tag{4}$$

where $\kappa_p \equiv \xi_p\omega_p$ and (3) and (4) are New Keynesian Phillips curves for price and wage inflation, and

$$w_t = w_{t-1} + \pi_t^w - \pi_t \tag{5}$$

is an identity for the real wage ($w_t = W_t/P_t$) expressed in logs and rearranged to provide a law of motion for the log of nominal wages. Here w_t is the log of the real wage, w_t^n represents exogenous variation in the natural real wage, and π_t^w is nominal wage inflation. This is a cashless economy as in Woodford (2003). The parameters $0 \leq \gamma_p \leq 1$ and $0 \leq \gamma_w \leq 1$ represent the degree of indexation to past inflation for price and wage inflation, respectively. Prices and wages are adjusted *à* la Calvo, where $1 - \alpha_p$ $(1 - \alpha_w)$ is the probability that the price (wage) is adjusted each period.[8]

The parameter ξ_p represents the sensitivity of goods-price inflation to changes in the average gap between the marginal cost and current prices; it is smaller as prices are stickier (α_p). The parameter ξ_w indicates the sensitivity of wage inflation to changes in the average gap between households' "supply wage" (the marginal rate of substitution between labor supply and consumption) and current wages, and it is a function of the Calvo parameter that denotes wage stickiness in the economy (α_w). The terms ξ_p and ξ_w are positive. The expression $\omega_p > 0$ represents the elasticity of the marginal cost with respect to the quantity supplied at a given wage, while $\omega_w > 0$ measures the elasticity of the supply wage with respect to the quantity produced, holding fixed households' marginal utility of income.

In order to estimate the system of equations, I substitute the law of motion for wages (5), into the Phillips curve for wages (3). In addition, I rewrite the Phillips curve for prices and wages in terms of $W_t = w_t - w_t^n$, where the shock in the Phillips curve for wages becomes $u_t^w = -w_t^n - w_{t-1}^n + \beta E_t w_{t+1}^n - \beta E_t w_t^n$.

The term r_t^n is the demand shock, and u_t^p and u_t^w are the supply shocks and they follow AR(1) processes:

$$r_t^n = \rho_r r_{t-1}^n + v_t^r, \tag{6}$$

$$u_t^p = \rho_p u_{t-1}^p + v_t^p, \tag{7}$$

$$u_t^w = \rho_w u_{t-1}^w + v_t^w, \tag{8}$$

where $v_t^r \sim iid(0, \sigma_r^2)$, $v_t^p \sim iid(0, \sigma_p^2)$, and $v_t^w \sim iid(0, \sigma_w^2)$.

Policymakers' Beliefs

Policymakers are assumed to have imperfect information about the model of the economy and the model's parameters. For that reason, policymakers approximate the true model of the economy by estimating a vector autoregressive (VAR) model whose reduced form is consistent with the rational expectations expression for the model. Policymakers do not know the true parameters of the model and estimate their values using a form of discounted least squares (i.e., constant gain least-squares learning (CGL)). Conditional on their estimated model for the economy, they choose their policy instrument to minimize their loss function.

The Policy Objective Function under Imperfect Information

Policymakers set monetary policy optimally according to the quadratic loss function described below:

$$E_t \left\{ \sum_{j=0}^{\infty} \beta^j [(\pi_{t+j})^2 + \lambda_w (\pi^w_{t+j})^2 + \lambda_x (x_{t+j})^2 + \lambda_i (i_{t+j} - i_{t+j-1})^2] \right\}. \tag{9}$$

The parameters for policymakers' preferences are illustrated by the weights assigned to the different stabilizing objectives represented by λ_w, λ_x, and λ_i in the quadratic loss function. Following the convention of the literature that estimates the weights of the central loss function, the weight assigned to inflation stabilization is normalized to 1.

The policy objective function takes the standard quadratic form with a preference for interest-rate smoothing studied in previous papers that assume that U.S. monetary policy is set optimally (Dennis, 2006). In this model, the central bank's objective is to minimize a quadratic loss function that reflects the goals of stabilizing the output gap, wage inflation, and deviations of the nominal interest rate from its lagged value relative to inflation stabilization.[9]

Policymakers minimize their welfare loss function (9) subject to the following perceived constraints, written in VAR form:

$$y_t = \hat{\mu} + \hat{\Gamma} y_{t-1} + \hat{Z} i^f_{t-1} + \epsilon_t, \tag{10}$$

where $y_t = [x_t, \pi_t, W_t]'$ and i^f_t is the actual short-term interest rate.[10] The matrices $\hat{\mu} = [\hat{c}_y, \hat{c}_\pi, \hat{c}_w]'$, $\hat{\Gamma} = [\hat{b}_1, \hat{b}_2, \hat{b}_3; \hat{c}_1, \hat{c}_2, \hat{c}_3; \hat{d}_1, \hat{d}_2, \hat{d}_3]$, and $\hat{Z} = [\hat{b}_4, \hat{c}_4, \hat{d}_4]'$ contain the coefficients that represent the policymakers' beliefs about the reduced-form parameters in the econometric model of the economy for the output gap, price inflation, and wage inflation, respectively.

The optimization constraints have the following state-space representation:

$$z_{t+1} = C_t + A_t z_t + B_t i_t + e_{t+1} \tag{11}$$

where $z_t = [x_t,\ x_{t-1},\ \pi_t,\ \pi_{t-1},\ \pi_{t-2},\ W_t,\ W_{t-1},\ W_{t-2},\ i_{t-1},\ i_{t-2}]'$ is the state vector, $e_{t+1} = [e^y_{t+1}, 0, e^\pi_{t+1}, 00, e^w_{t+1}, 0, 0, 0, 0]'$ is the shock vector, and i_t is the control variable. The matrices in the state-space form are included in the Appendix A. Policymakers' beliefs about the model's coefficients are represented by circumflexes. This imperfect model of the economy is estimated on inflation, output gap, detrended wages, and lagged short-term interest rate data.[11]

Learning

Policymakers estimate the parameters of the VAR model by CGL. CGL is a form of discounted recursive least-squares learning sensitive to environments with structural change of unknown form.[12] The constant gain parameter **g** governs how strongly past data are discounted; the larger the gain coefficient, the more rapid is the learning of structural breaks, and the more volatile are the learning dynamics.

The VAR coefficients are computed by updating previous estimates as additional data on output, inflation, wages, and lagged short-term interest rates become available. The recursive formulas used are

$$\widehat{\phi}^j_t = \widehat{\phi}^j_{t-1} + \mathbf{g} R^{-1}_{j,t-1} \chi_t (\zeta^j_t - \chi'_t \widehat{\phi}^j_{t-1}) \tag{12}$$

$$R_{j,t} = R_{j,t-1} + \mathbf{g}(\chi_t \chi'_t - R_{j,t-1}), \tag{13}$$

where $j = \{x, \pi, W\}$, $\zeta_t \equiv [x_t, \pi_t, W_t]'$ is a vector of endogenous variables and $\chi_t \equiv [1, \zeta_{t-1}, i_{t-1}]$ is a matrix of regressors, **g** is the gain coefficient, and $\widehat{\phi}^{x_t}_t = [\widehat{c}_y, \widehat{b}_1, \widehat{b}_2, \widehat{b}_3, \widehat{b}_4]'$, $\widehat{\phi}^{\pi_t}_t = [\widehat{c}_\pi, \widehat{c}_1, \widehat{c}_2, \widehat{c}_3, \widehat{c}_4]'$, $\widehat{\phi}^{w_t}_t = [\widehat{c}_w, \widehat{d}_1, \widehat{d}_2, \widehat{d}_3, \widehat{d}_4]'$ collect the reduced-form parameters. The updating rule for the central bank's beliefs is represented by (12), while (13) describes the updating formula for the precision matrix of the stacked regressors $R_{j,t}$. The updating formulas correspond to a discounted least-squares estimator.

Optimal Policy

Policymakers minimize their welfare loss function (9) subject to the VAR model of the central bank (10). Following Sargent (1987), the solution to this stochastic linear optimal regulator problem is the optimal policy rule:

$$i_t = F(\hat{\phi}_t)z_t, \tag{14}$$

The solution to the policy problem is a function of the perceived VAR parameters $\hat{\phi}_t = [\hat{c}_y, \hat{b}_1, \hat{b}_2, \hat{b}_3, \hat{b}_4, \hat{c}_\pi, \hat{c}_1, \hat{c}_2, \hat{c}_3, \hat{c}_4, \hat{c}_w, \hat{d}_1, \hat{d}_2, \hat{d}_3, \hat{d}_4]'$ and the state variables z_t. The value for the optimal monetary policy variable i_t will embed the policymakers' beliefs about the state of the economy. Notice that these beliefs influence the direction of the economy through i_t.

The policy rule (14) can be rewritten as

$$i_t = F_x x_t + F_\pi \pi_t + F_w \pi_t^w + F_{il} i_{t-1}^f. \tag{15}$$

The structural model consists of (1)-(5) along with the solution to the optimal policy problem expressed in structural form given by (15). To solve and estimate the model, some assumptions are made with regard to the private sector's expectation formation process. As in Primiceri (2006) and Sargent (1999), the private sector knows the policymakers' actions. In particular, private agents in the economy know the policymakers' model given by (10), as well as the policymakers' loss-minimizing problem that yields the policy variable i. I follow most of the adaptive learning literature in that the private sector assumes policymakers are "anticipated utility" decision makers (Kreps [1998]).[13] Agents believe that policymakers will continue to implement policy based on their last estimate of (15).[14] Notice that the private sector in this economy has rational expectations and takes the central bank's optimal policy rule as given, similar to Sargent (1999). Therefore, assuming that estimates $F(\hat{\phi}_t)$ in (14) will remain fixed into the future, (1)-(5), along with the solution to the optimal policy problem given by (15), constitute a linear rational expectations model.[15] Since the parameters in $F(\hat{\phi}_t)$ are estimated and therefore change every period as more information becomes available, the linear rational expectations model must be solved every period to find the time-varying data generating process. I estimate jointly the full set of structural, non-structural, and policy preference parameters along with the standard deviations (SDs) of the shocks.

Model Overview

It is useful to provide a brief overview of the economic model before turning to the estimation results. Policymakers use the time-series data on the variables in the economy to estimate the parameters in their model. The policymakers' perceived VAR is estimated over time by CGL. Policymakers solve their optimal control problem using the beliefs derived from their recursively estimated model to formulate a policy rule for i_t. The private sector takes that policy rule and forms rational expectations. The next section jointly estimates the preference parameters, gain coefficient, and the structural coefficients of the true model using Bayesian methods.

Estimation Strategy

I estimate the set of private sector structural parameters, the policy preference parameters, and the gain coefficient $\mathbf{g}$ using Bayesian techniques (An and Schorfheide [2007]) and data from 1960:Q2 to 2008:Q1. The private sector model parameters include the structural parameters and corresponding SDs of the shocks.

The gain coefficient dictates the speed of learning of the VAR model parameters, which constitute the policymakers' beliefs about the structure of the economy. The gain coefficient was estimated and not fixed to avoid obtaining results (including preference parameter estimates) dependent on parameters chosen by the researcher. The estimation approach balances the two competing hypotheses, ensuring that neither hypothesis (beliefs or preferences) is favored. The initial beliefs correspond to ordinary least-squares (OLS) estimates of the policymakers' model using data from 1954:Q2 to 1960:Q1; this sample coincides with Slobodyan and Wouters (2012b), who conclude that this sample choice for initial beliefs improves the fit of the model.

To test the hypothesis that shifting preferences may have played a role in the end of the Great Inflation, the preference parameters λ_w, λ_x, and λ_i are estimated (i) allowing for a (potential) structural break in 1979:Q3 (μ_1) coincident with the appointment of Paul Volcker as chairman of the Federal Reserve,[16] and (ii) using the full sample (μ_2). The preference parameters evolve according to the following $\lambda_{\varpi,t} = \begin{cases} \mu_1 \quad \lambda_{\varpi,pre-1979} & 1960:Q2 \leq \text{t} \leq 1979:Q2 \\ \quad\quad \lambda_{\varpi,post-1979} & 1979:Q3 \leq \text{t} \leq 2008:Q1 \\ \mu_2 \quad \lambda_{\varpi,full} & 1960:Q2 \leq \text{t} \leq 2008:Q1 \end{cases}$ where $\varpi = x, w, i$. The remaining parameters are estimated for the full sample.

Although the focus of the estimation has been on identifying a potential break in the preference parameters in the face of policymakers' learning about the economy, a large body of literature has considered also potential breaks in other parameters. To illustrate that there has indeed been a break in the preference parameter and that the detected break in the weights is not just a "proxy" for actual breaks in other parameters, I consider several other alternative specifications that will be furthered described in the Robustness section. After comparing the models' fit of the alternative specifications to the data, I find decisive evidence in favor of the model *Gains and SDs 1984*—now benchmark—that observes changes in the preference parameters, speed of learning, and volatilities of the shocks.

The interpretation of accounting for a potential change in the gain parameter is simple.[17] If policymakers are concerned that the economy is in the midst of a structural break, they start assigning a larger weight to new information, resulting in a higher gain. Conversely, if the central bankers are confident about their model of the economy, they respond more moderately to new information, yielding a relatively lower gain. Following Milani (2014) the gain coefficient is allowed to vary over time as in $\mathbf{g}_t = \begin{cases} \mathbf{g}_{pre-1979} & t < 1979:Q3 \\ \mathbf{g}_{post-1979} & t \geq 1979:Q3. \end{cases}$

The change in the volatility of shocks at the inception of the Great Moderation seems more abrupt than gradual, and Kim and Nelson (1999) and Stock and Watson (2003) concur that it occurred in 1984:Q3. I perform a split-sample analysis—as in Smets and Wouters (2007)—where the SDs of all shocks except the monetary policy shock are allowed to shift in 1984 according to:[18] $\sigma_{s_1,t} = \begin{cases} \sigma_{s_1,pre-1984} & t \leq 1984:Q3 \\ \sigma_{s_1,post-1984} & t \geq 1984:Q3 \end{cases}$ where $s_1 = r$, p, and w.

The SD of the monetary policy shock, moreover, observes a potential change between 1979:Q3 and 1982:Q4, during the "Volcker episode." This sub-sample analysis is deemed to capture the high volatility of interest rates due to the monetary targeting regime started by Volcker. The evolution of SDs of the shocks is described by $\sigma_{mp,t} = \begin{cases} \sigma_{mp,1979-1982} & 1979:Q3 \leq t \leq 1982:Q4 \\ \sigma_{mp,o/w} & o/w. \end{cases}$

Bayesian Estimation

The parameters are represented in a vector parameters denoted Θ. The vector Θ is designated by

$$\Theta = [\varphi, \eta, \xi_p, \omega_p, \omega_w \gamma_p, \gamma_w, \lambda_{x,t}, \lambda_{w,t}, \lambda_{i,t}, \rho_r, \rho_p, \rho_w, \sigma_{mp,t}, \sigma_{r,t}, \sigma_{p,t}, \sigma_{w,t}, \mathbf{g}_t]'. \tag{16}$$

The vector of observed variables consists of the output gap, the inflation rate, the deviation of the log real wage from trend, and the optimal policy variable, i_t, obtained within the model, Y_T=[x_t, π_t, W_t, i_t]. A prior distribution is assigned to the parameters of the model and is represented by $p(\theta)$. The Kalman filter is used to evaluate the likelihood function given by $p(Y^T|\theta)$, where $Y^T = [Y_1, ..., Y_T]$. Finally, the posterior distribution is obtained by updating prior beliefs through Bayes' rule taking into consideration the data reflected in the likelihood.

I estimate the posterior distribution for all models described in the Estimation Strategy section through a Metropolis Hastings algorithm.[19] The specific simulation method used is random walk Metropolis-Hastings, for which I ran at least 500,000 iterations, discarding the initial 20% as burn-in. In addition, I ran several other chains with different initial values and obtained similar results.

Data

The estimation was performed using quarterly data on the output gap, inflation, real wage, and nominal interest rates. Inflation is measured by the quarterly change of the GDP implicit price deflator. The output gap for the private sector model is the log difference of the gross domestic product (GDP) and potential GDP estimated by the Congressional Budget Office. The real wage is measured by the log of the nonfarm business sector real compensation per hour from the Bureau of Labor Statistics. Lastly, the nominal interest rate is represented by the federal funds rate. All data are from Federal Reserve Economic Data (FRED); Federal Reserve Bank of St. Louis.

Priors

Table 2 presents prior distributions along with their means and SDs for the parameters included in Θ. The prior for the parameter φ has a gamma distribution with a mean 1, and an SD of 0.50 that is slightly lower than in Milani (2007). The priors for habit persistence, and price and wage inflation indexation follow a beta distribution with mean of 0.70 and SD of approximately 0.20. This prior aids at estimating parameters because it prevents posterior peaks from being trapped at the upper corner of the interval. I use an inverse gamma as prior density for the shocks' SD. The prior for ξ_p, which is a function of price stickiness, follows a normal distribution centered at 0.015, which was the value assigned in Milani (2007). Furthermore, ω_p and ω_w follow a gamma distribution with a mean 0.89 and a large SD of 0.40; a gamma distribution was assigned in this case because the model assumes that these parameters take positive values.

Table 1 located here.

The priors for the weights on the policymakers' loss function are informative. They are centered at the values implied by the microfounded weights derived in Giannoni and Woodford (2003). The implied microfounded weights are functions of the underlying model parameters. The priors of the loss-minimizing rates of wage inflation, deadweight loss, and interest-rate-smoothing parameter follow a gamma distribution. The loss-minimizing rates of wage inflation, as well as the deadweight loss, are centered at 0.30. These means are approximated by taking the values of the structural estimates in the model and calculating the various stabilization objectives as functions of the underlying model parameters, implied by the microfounded loss function. The prior for the interest-rate-smoothing parameter has its mean approximately at the value obtained by Dennis (2006).

Results

Model Fit

The first results to consider are the measures of the model fit to the data; the comparison of all models was performed based on marginal data densities. The log marginal likelihoods computed using Geweke's modified harmonic mean approximation are presented in Table 2, along with the posterior odds ratio. Of note, the marginal data densities are presented on a log-likelihood scale, implying that differences of 1 or 2 in absolute value are of little importance, whereas differences of 10 or more indicate decisive evidence favoring the model with higher marginal density. The best-fitting model is *Gains and SDs 1984* with a difference of 10 or more over the rest of the models. I now proceed to report the result for the benchmark model.

Table 2 located here.

Parameter Results

Table 3 presents parameter results for *Gain and SDs 1984*. The results show a shift in policymakers' preferences away from output gap stabilization after the appointment of Chairman Volcker. In the pre-Volcker period, the estimated weight on output stabilization ($\lambda_{x,pre-1979}$) was 1.034; this value decreased significantly in the post-Volcker period ($\lambda_{x,post-1979}$) to 0.150. This change in preferences for output gap stabilization relative to inflation is akin to Dennis (2006).[20] He finds that the estimated weight on the output gap is not significantly different from zero in the post-Volcker era. He suggests that the Federal Reserve did not have an output stabilization goal during this period and that the reason the output gap is significant is because it contains information about future inflation.

Table 3 located here.

The estimated interest-rate-smoothing weights are ($\lambda_{i,pre-1979} = 0.210$) and ($\lambda_{i,post-1979}= 0.140$). Although the interest-rate-smoothing term is relatively higher in the pre-Volcker period, the posterior probability intervals overlap, implying that the weights are roughly similar. Finally, the weight that central bankers assigned to wage inflation increases from ($\lambda_{w,pre-1979} = 0.210$) to ($\lambda_{w,post-1979} = 1.10$) in the Volcker-Greenspan period; this is consistent with the inflation stabilization goals persistent in the post-Volcker period documented in the literature.

One contribution of this paper is that it estimates the weights in the central bank's loss function along with the structural parameters in the model. The parameters assume plausible values similar to previous Bayesian estimations of New Keynesian DSGE models for the United States (Lubik and Schorfheide [2004]; Milani [2007a, 2011, 2012]; Smets and Wouters [2007]; Slobodyan and Wouters [2012b]) and estimations that match model-based impulse responses and VAR impulse responses (Giannoni and Woodford, 2003). The price stickiness parameter ($\xi_p = 0.003$) is consistent with the findings of Giannoni and Woodford (2003) and Milani (2007). The estimate for habit formation in consumption ($\eta = 0.119$) is low compared with Smets and Wouters (2007); however, it is still in the range of Milani's findings. The degrees of price indexation ($\gamma_p = 0.190$) and wage indexation ($\gamma_w = 0.552$) are in line with the estimates in Smets and Wouters (2007), and Giannoni and Woodford (2003). They find a lower degree of price indexation than wage indexation. The pseudo-intertemporal elasticity of substitution ($\varphi = 3.474$) relates to the estimates of Lubik and Schorfheide (2004) and Milani (2007). The autoregressive component of the shocks ($\rho_r = 0.866, \rho_w = 0.99$, and $\rho_p = 0.453$) is highly persistent and analogous to estimations of models that observe rational expectations. It is worth noting that all parameters support estimations of DSGE models with rational expectations, except for the degree of habit persistence that mimics the findings of Milani (2007).[21]

The benchmark model also captures a change in the SDs of the shocks in demand and supply ((1) and (3)) motivated by the literature on the Great Moderation. The result supports the documented decrease in volatility of these shocks in the post-1984 era from ($\sigma_{r,pre-1984} = 0.208$ and $\sigma_{p,pre-1984} = 0.413$) to ($\sigma_{r,post-1984} = 0.092$ and $\sigma_{p,post-1984} = 0.277$). Moreover, the results also point to a higher SD of the monetary policy shock during the Volcker episode ($\sigma_{mp,1979-1982} = 0.025$) compared with the rest of the sample ($\sigma_{mp,o/w} = 0.004$).

The data are also informative in the estimation of the gain coefficient **g**. The speed of learning decreased considerably from $\mathbf{g}_{pre-1979} = 0.029$ to $\mathbf{g}_{post-1979} = 0.006$ in the post-Volcker era. Intuitively, before 1979, policymakers were responsive to their suspicion of potential structural breaks in the economy, supported by the uncertain economic climate. Furthermore, after 1979, with the change in preference toward inflation stabilization and the unfolding of the Great Moderation, central bankers increased their trust in their model of the economy and responded more moderately to new information, resulting in a lower gain. The values estimated for the gain parameter are plausible and are within the range of previous estimations (i.e. Slobodyan and Wouters [2012b] find a gain between 0.001 and 0.034). Milani (2014) also estimates the gain coefficients that are allowed to adjust according to past forecast errors in a model that generates time-varying macroeconomic volatility. His estimation results show that private agents switched to a constant gain with high learning during the 1970s into the early 1980s to revert to a decreased gain later. Thus, policymakers' learning in this paper coincides with agents' speed of learning patterns (see Milani, 2014) over the sample studied.

Therefore, I observe a monetary policy regime change from the pre-Volcker era into the Volcker-Greespan era, even in the presence of policymakers evolving beliefs about the structure of the economy and the changing volatility of the shocks capturing the Great Moderation.

Policymakers' Beliefs and the Great Inflation

This section explores how evolving policymakers' beliefs played a role in the Great Inflation. As previously described, I find a change in policymakers' preferences away from output gap stabilization toward inflation stabilization after 1979. One reason that policymakers followed a relatively low inflation stabilization goal before 1979, even in the face of high inflation, could be their real-time beliefs regarding the persistence of inflation in the Phillips curve and the slope of the Phillips curve. This paper finds empirical support for the hypothesis that policymakers' evolution of beliefs—akin to the "overoptimistic" and "overpessimistic" explanation described in Primiceri (2006) and Romer and Romer (2002)—contributed to propagate the Great Inflation.

Figure 1 located here.

Fig. 1 plots the real-time estimates of the AR(1) coefficient $\hat{c}_2$, which represents a measure of perceived inflation persistence starting in 1960s. During the early stages of the Great Inflation, in the model policymakers do not react strongly to inflation because they perceived a low real-time estimate of the persistence of inflation—coined the "overoptimistic" period of the Great Inflation.[22] Policymakers perceived that inflation would revert to its mean value at any time. Their estimates of the persistence of inflation were slowly revised upward, reaching a value close to 0.90 in 1975.[23]

The perceived persistence of inflation remains high until the early 1980, then reverts to its pre-1975 values in the Volcker disinflation period. These dynamics are standard and consistent with Orphanides and Williams (2005) and Cogley, Primiceri and Sargent (2010). While Cogley, Primiceri and Sargent (2010) propose that monetary policy and non-policy factors contributed to the dynamics of the persistence of inflation, Orphanides and Williams (2005) suggested that inflation expectations were well anchored during the beginning of the sample. However, the aggressive response to the output gap unleashed inflation expectations that resulted in the increase in inflation persistence in 1975.

Orphanides and Williams perform simulation exercises and conclude that the perceived persistence of inflation in the late 1970s would have been roughly between 0.50 and 0.75 had the Fed followed the post-1979 inflation stabilization strategy, and not responded strongly to the output gap.[24] In sum, policymakers perceived a low real-time estimate of the persistence of inflation before 1975, which explains the passive behavior of policymakers toward inflation at that time.

Figure 2 located here.

Figure 2 plots the real-time estimates of the sensitivity of inflation to changes in the output gap, coefficient $\hat{c_1}$, of the perceived Phillips curve during the period of study. The representation of the perceived Phillips curve is consistent with this paper's New Keynesian model of the economy in which deviations of real GDP from potential affect inflation. This representations resembles that of Primiceri (2006), but it differs from those Sargent (1999), Cogley and Sargent (2005), Carboni and Ellison (2009), and Pruitt (2010), in whose models policymakers affect real activity by directing inflation. This is an important strand of research, but in this case I follow Primiceri (2006).[25]

While the slow revision of the persistence of inflation toward its high value of 0.90 in the mid-1970s would signal the need for policymakers to strengthen the response to inflation, what Primiceri (2006) calls a "perverse" mechanism prevented policymakers from taking such course. Figure 2 suggests that in the mid-1970s, policymakers revised their perception of the output gap–inflation trade-off toward zero, deeming it very unfavorable. This period is referred to as the "overpessimistic" period of the Great Inflation, which followed the "overoptimistic" period.[26] This would decrease the perceived strength of the policy reaction toward inflation. Policymakers noticed that pushing output below its potential would reduce inflation only slightly.[27] As discussed by De Long (1997), the perceived cost of fighting inflation was not acceptable until the estimated trade-off between the output gap and inflation improved in the 1980s. Notice that Figure 2 suggests that only *after* policymakers changed their preference, favoring an inflation stabilization goal, did the perceived cost of fighting inflation decrease. This finding implies that policy directed to stabilize inflation was put in place *before* the perceived output gap–inflation trade-off improved.

In other words, preferences toward inflation stabilization had to change in order to explain the disinflation episode. This result supports the finding in Cecchetti et al. (2007) of the willingness of central bankers in the inflation stabilization era to use disinflation even if that translated into a painful unemployment episode. Therefore, monetary policy regime changes were, in fact, important to large movements in the rate of inflation in the United States.

To grasp the monetary policy strategy followed by policymakers in the benchmark model, Figure 3 plots the evolution of the estimated model's optimal policy variable over time. The federal funds rate is also plotted for comparison. As shown, the model's optimal policy variable closely follows the behavior of the federal funds rate in the study period.

Figure 3 located here.

In addition, Figure 4 depicts the optimal policy variables simulated for μ_2: the model estimated without a change in preferences in 1979. The most striking feature of this figure is that the estimated model's optimal policy variable from the 1960s to the mid-1980s is consistently above the federal funds rate, while the variable is below the fed funds rate from the mid-1980s to 2008 for selected periods. Therefore, not only do the data favor the model with a regime switch in 1979, but their implied optimal policy variable also better matches the evolution of the federal funds rate for the full sample.

Figure 4 located here.

Change in Preferences, Changes in Policymakers' Beliefs, and Their Implied Taylor Rule Coefficients

To interpret the changes in the stabilizing weights for the inflation rate, output gap, and interest rate change, I study their implied optimal interest rate responses. Of note, the interest rate responses are reduced-form representations of policymakers' behavior and their responses often hide the difference between policymakers' objectives: factors that the central bank can control and those it cannot control. Therefore, the policymakers' preference parameters can better capture the changes in central bank objectives.

Figure 5 located here.

Figure 5 presents the response to inflation (price and wage combined), and Figure 6 presents the response to the output gap and interest-rate-smoothing term in the time-varying policy reaction function implied by (15).[28]

The results obtained from the optimal time-varying policy reaction function implied by the model agree remarkably in magnitude and follow the same pattern as the Fed's time-varying responses in Boivin (2006), Kim and Nelson (2006), and Ang et al. (2011). These authors estimate time-varying policy reaction functions that account for heteroskedasticity in the policy shock, endogeneity of the regressors, and the term structure of interest rates, respectively.[29] The time-varying coefficient on inflation is also consistent with the narrative evidence of the evolution of monetary policy theory and understanding provided in Romer and Romer (2002). The time-varying coefficient for inflation presented in Figure 5 evolves as follows: The Fed pursues a monetary policy easing strategy represented by a low response to inflation during the early 1960s and most of the 1970s, until 1979. In fact, the Fed's response to inflation during the 1970s was the lowest throughout the whole sample (> 1), indicating that the Fed accommodated inflation on a few occasions. The Fed's inflation response increases sharply in the late-1979s (settling at ~ 2), stays at a high level during the 1980s, and starts to decrease in the early-1990s. There is a further increase in the inflation coefficient in the mid-1990s, consistent with the Fed's desire to use pre-emptive measures to fight inflation. The 2001 recession is accompanied by a decreased response to inflation that remains through 2003. Finally, I observe a decrease in the response to inflation in the prelude to and amidst of the Great Recession.

Figure 6 located here.

Figure 6(a) represents the time-varying policy coefficient for the output gap from 1960 to 2008. During most of the 1970s, policymakers used their policy instrument in an attempt to influence the output gap, but this approach changes after 1979 (see Boivin [2006]). In Volcker's disinflation period, the response of the interest rate to the output gap decreases and was nearly half of its pre-1979 magnitude. Once inflation was stabilized, the Fed increased its reaction to real economic conditions during the 1990s.[30] The dynamics of the time-varying policy coefficient are identical to the findings in Kim and Nelson (2006).[31]

The time-varying interest-rate-smoothing parameter is shown in Fig. 6(b). This parameter increases gradually during the entire sample and its dynamics are consistent with Boivin (2006) and Kim and Nelson (2006). In fact, I observe a sharp and short-lived reduction in the early 1980s, akin to Boivin's findings. Although the estimates of interest rate smoothing seem lower (in the earlier portion of the sample) than those found in the literature, these values are within the confidence bands estimated in Kim and Nelson (2006).

Counterfactual analysis

In an attempt to understand the contribution of the change in policymakers' preferences compared with the changes in beliefs, a series of counterfactual experiments were conducted in which all but the relevant parameters are fixed at their benchmark values.

In the first experiment, I fix the policy preference parameters to their pre-1979 estimates and analyse their implied time-varying Taylor rule policy responses.[32] The marked preference for output gap stabilization would have prevailed in the post-1979 period, resulting in a high time-varying response to the output gap; moreover, a low time varying response to inflation consistent with policy accommodation would have continued in the post-1979 period. These patterns are opposite to the dynamics present in the benchmark model, especially during Volcker's disinflation. The optimal federal funds rate for the pre-1979 counterfactual experiment is depicted in Figure 7. This variable would have been roughly half of the actual value reached by the federal funds rate in the late 1970s and early 1980s, and would have been inconsistent with the Fed's disinflation strategy.

Figure 7 located here.

The second experiment fixes the policy preference parameters to their the post-1979 values, yielding the following dynamics for the Taylor rule coefficients: the reported increase in the time-varying response to the output gap in the 1970s is absent, except for a short stint in 1975; the time-varying response to inflation would have been aggressive, roughly around 2, and consistent with its post 1970s level. Interestingly, Figure 8 shows that (i) the optimal federal funds rate would have been above the actual federal funds rate after 1965. (ii) We would have observed a more dramatic increase in the policy instrument in the first peak of the federal funds rate in the early 1970s, possibly anchoring inflation expectations during the rest of the sample. And (iii) the second peak in the federal funds rate in the 1970s would have occurred sooner, probably taming inflation earlier. These findings suggests that post-1979 policy would have resulted in a more aggressive response to inflation at an earlier date compared with the actual federal funds rate.

Figure 8 located here.

Figure 9 plots the optimal federal funds rate in a counterfactual experiment with no learning. In particular, I simulate the optimal federal funds rate for the benchmark model with a zero constant gain coefficient. In this setting, policymakers would have observed a change in preference in 1979:Q2, but no learning about the evolution of the structure of the economy over time would have occurred. Their beliefs about the structure of the economy would have remained at their initial values.[33] I find that the *evolution of beliefs* about the structure of the economy, especially when policymakers' are facing an unstable environment, is important to capture the dynamics of the policy instrument over the period of study. No learning would have resulted in a low optimal federal funds rate, missing the dynamics and magnitude of the federal funds rate during most of the sample. Intuitively, policymakers would have kept their overly optimistic view of the Great Inflation, resulting in a low optimal federal funds rate. In fact, learning about the structure of the economy is also important in the more recent period because it justifies the dynamics of the policy instrument.

Figure 9 located here.

An additional counterfactual experiment was performed in which the optimal federal funds rate is simulated for the benchmark model assuming that the gain parameter is fixed at its post-1979 value ($\mathbf{g}_{post-1979}$) of 0.006. The simulated policy variable is plotted in Figure 10. I find that under the low gain assumption, the optimal federal funds rate is consistently above the actual federal funds rate during the mid- to late 1970s and peaks at 15, a value considerably higher than the actual fed funds rate.

Figure 10 located here.

Intuitively, this low gain affects the beliefs about the structure of the economy in the following way: The policymakers' perceived persistence of inflation increases to $0.85 - 0.90$ roughly around 1975 and stays at a high constant value for the rest of the decade. The downward revision of the persistence of inflation during Volcker's disinflation period is not present. This belief would have reinforced the policymakers' signal to respond strongly to inflation. Moreover, perceptions about the inflation–output gap trade-off are now advantageous during the mid- to late 1970s, vindicating the counterfactual's aggressive increase in the policy instrument during the late 1970s.[34]

Robustness

Other Specifications

In this section, I discuss the results for the additional sets of specifications where the model not only allows for a monetary policy regime change, but it also permits different (i) speeds of learning, (ii) volatilities, and (iii) structural parameters.

Table 4 presents the parameter results in models that introduces a change in policymakers' preferences in 1979 (μ_1), no change in preferences (μ_2), and a change in policymaker's preferences along with a potential break in the gain coefficient in 1979 ($Gain$).[35] The models μ_1 and $Gain$, that exhibit a policy shift in 1979, have a better fit to the data than model μ_2; in fact, both models confirm the conclusion reached for the benchmark model: The weight assigned to the output gap in the loss function is higher in the pre-Volcker period ($\lambda_{x,pre-1979} = 0.575$ and 0.649) compared with the post-Volcker episode ($\lambda_{x,post-1979} = 0.0060$ and 0.018). There is also evidence of change in the gain coefficient from the pre-1979 sample (0.018) to the post-1979 sample (0.006).[36]

Table 4 located here.

Additionally, models *Gains and SDs 1979* and *SDs 1979* examine the possibility of a concurrent change in preferences and SDs in 1979, with and without a change in the gain parameter in 1979, respectively.[37] Results corroborate that in both models, the weight assigned by central bankers to output gap stabilization was higher in the pre-Volcker period than in the post-Volcker period. What is somewhat puzzling is that the SDs of the shocks do not monotonically decrease in the post-1979 period; this result led to the estimations of models that allow for a break in the volatilities of the shocks consistent with the Great Moderation and the Volcker episode—*SDs 1984*, *Gains and SDs 1984*, and *All*.[38] These models not only have a superior fit to the data, they also provide further support to the policy regime shift hypothesis of this paper, as well as a change in the volatilities of the shocks consistent with the Great Moderation literature. However, I found no evidence of a change in the structural parameters of the private sector model in 1979 in the *All* model; 95% posterior probability intervals overlap between samples (see Smets and Wouters, 2007).

To summarize, the data support a policy regime change in 1979, consistent with the idea that policymakers changed their preference for output gap stabilization in the post-1979 era. This is the case even after accounting for a break in the SDs of the shocks in the onset of the Great Moderation and a change in the speed of policymakers' learning about the structure of the economy.

VAR(2)

This section examines the robustness of results to a different assumption regarding the number of lags in the central bank's model. The central bank's model of the economy is now portrayed as a VAR(2) for output gap, inflation, and detrended wages as in Primiceri (2006) and Pruitt (2010),

Table 10 presents the parameter estimates. The main result is robust to having a model of the central bank in which a different lag length is considered. I find there was a shift in preferences for inflation stabilization after 1979. The weight on the output gap decreases to 0.005 in the post-Volcker era, which is in accordance with Dennis (2006) estimates, while in the pre-Volcker era the same parameter is 0.159; the posterior probability intervals do not overlap showing a significant difference between samples. In addition, the weight on the wage inflation parameter is higher in the post-Volcker period, 1.009, compared to its pre-1979 estimate of 0.764. However, in this case, the fit of the model to the data is the worst compared with any of the models where the learning rule follows a VAR(1) model.[39] The VAR(1) assumption is very common in the literature.

Conclusions

The rise and subsequent fall of inflation in the United States during the 1970s and 1980s—the Great Inflation—has been the subject of extensive research. One approach holds that the Federal Reserve held misperceptions about the state of the economy and the transition equations for the economy. An alternative explanation contends that monetary policymakers during the late 1960s and throughout the 1970s preferred stabilizing output, whereas after 1979 they preferred inflation stabilization. This paper studies the Great Inflation in a medium scale macroeconomic model that embeds both (i) changing beliefs, through learning, about the state of the economy (ii) a possible change in policymakers' preferences from the Great Inflation into the inflation stabilization era. When both elements are combined, the empirical results illustrate the extent to which changes in either the *perceived or the preferred* inflation–output gap trade-off explain the Great Inflation.

This paper provides evidence of a shift in preferences by central bankers to output gap stabilization relative to inflation stabilization after 1979, even in the presence of policymakers who are learning about the state of the economy over time. In the pre-Vocker period, the central bank's objective in this model is to stabilize the output gap. However, after Volcker's appointment the relative weight agreed on by central bankers to stabilize the output gap approaches zero. This result suggests that policymakers in the 1970s concerned about output gap stabilization were still mindful of Great Depression (De Long [1997]) and did not make policy decisions that would translate into a sizeable recession. Even though there was no mandate to fight inflation by allowing the unemployment rate to rise during the late 1960s and most of the 1970s, this changed by 1979. Policymakers then fought inflation by inducing a significant recession as a result of fears about the cost of inflation.

The responses of the output gap and inflation (wage and price) in the time-varying policy reaction function implied by the model are consistent with previous estimates of time-varying Taylor rule coefficients and narrative evidence of the evolution of monetary policy theory and understanding. Therefore, *both* policymakers' learning and changes in preferences are needed to represent the Fed's time-varying policy response to inflation and to explain the dynamics present in the Fed's policy instrument.

Notes

[1]There are a number of hypotheses on the causes of the Great Inflation (e.g., bad monetary policy, "bad luck" sequence of shocks, and lack of commitment to low inflation policies).

[2] An additional explanation for the Great Inflation, separate from the distorted beliefs hypothesis, was examined by Romer and Romer (2002) and Nelson (2005). These authors conclude that during the 1970s policymakers dabbed in nonstandard policy, such as price and wage controls, because they believed that inflation was impervious to slack.

[3] The change in preference hypothesis has been supported in papers that estimate the objective function of the Fed (e.g., Dennis [2006]) and in regime-switching models (e.g., Owyang and Ramey [2004]). Owyang and Rammey conduct a study of the use of regime switching for estimating monetary policy preferences. The estimates display switches to dove regimes that Granger-cause the Romer dates. The Romer dates demarcate the Fed's intent to exert contractionary monetary policy to reduce inflation, thus supporting the view that there were changes in policymakers' preferences, especially around 1979.

[4]A recent paper by Slobodyan and Wouters (2012a) that incorporates learning in a DSGE model finds that the observed decline in the mean and the volatility of inflation is attributed to beliefs about the inflation persistence.

[5]Details on the model derivation are available upon request.

[6]Recent work has shown that staggering of nominal wage contracts is important to give rise to key frictions that render monetary policy non-neutral. In fact, Christiano, Eichenbaum, and Evans (1999 and 2005), Smets and Wouters (2003), and Altig et al. (2011), conclude that wage stickiness—not price stickiness—appears to be more important in explaining output and inflation dynamics.In particular, Christiano, Eichenbaum, and Evans (1999) analyze impulse responses to an unexpected interest rate reduction and find a slightly procyclical real wage movement. The explanation

for this modest response of real wages is that there is a slow wage adjustment to any given change in labor demand. This validates wage stickiness as an important factor in explaining the real effects of monetary policy.

[7]I denote $\sigma > 0$ as the inverse of the intertemporal elasticity of substitution, $\beta \in (0,1)$ as the household's discount factor, and $0 \leq \eta \leq 1$ as the measure of habit persistence in consumption. As in Giannoni and Woodford (2003), the parameter φ, which has been called the inverse of the pseudo-elasticity of intertemporal substitution, is estimated instead of σ.

[8]The probability is independent of the time since a given price (wage) was last adjusted.

[9]There are several reasons why interest-rate smoothing is a compelling property of the loss function. One reason is that maturity mismatches between banks' assets and volatilities make financial volatility an undesirable property, as addressed by Cukierman (1989). In addition, if policymakers have to retract from a large interest rate movement, it may lead to lost credibility and reputation, as described by Brainard (1967). Dennis (2006) outlines these and other reasons why interest rate smoothing is a desirable feature of the loss function.

[10]In the estimation, the lagged federal funds rate was used as a proxy for the previous short-term interest rate.

[11]The central bank model of the economy was also estimated using a VAR(2). The results are presented in the Robustness section. The results also support a change in preferences for inflation stabilization, as represented by the weights on the central bank loss function.

[12]Under CGL, learning dynamics will converge to a distribution around the rational expectations equilibrium.

[13]Policymakers estimate the parameter in their model and treat them as true vales, neglecting the possibility of future updates.

[14]An alternative specifications would be to have a "fully rational" private sector that takes into account that policymakers revise their estimates about the model on the basis of future data. However, Primiceri (2006) concludes that having fully rational agents is probably too strong and at odds with the data on the disinflation period

[15]The rational expectations model was solved using Sims (2002).

[16]Boivin (2006) using drifting coefficients and real time data, Duffy and Engle-Warnick (2006) using nonparametric methods, and Romer and Romer (1989)—RR henceforth—using the narrative approach, also identify a policy switch in the 1979:Q3, among many others.

[17]Marcet and Nicolini (2003) and Milani (2014) have studied changes in changes in the learning speed. In fact, Milani (2014) finds a shift in the speed of learning in the early 1980s.

[18]Justiniano and Primiceri (2008), Fernandez-Villaverde and Rubio-Ramirez (2007), and Milani (2014) study in depth the time variation of the volatilities of the shocks in a DSGE setting. This is an interesting avenue to explore in the present context; however, I abstract from this complication at the moment due to the computational demand of the current algorithm.

[19]Refer to Chib and Greenberg (1995) for details on the specification of the Metropolis-Hastings algorithm.

[20]Dennis estimates the parameters in the Federal Reserve's policy objective function along with the parameters in the optimizing constraints.

[21]A standard result in the literature that replaces learning with rational expectations (i.e. Milani [2007]; Slobodyan and Wouters [2012a]) finds that the highly persistent component of the shocks to price and wage inflation disappear, along with the subdued role of price and wage indexation. Milani also points to a lower degree of habit persistence by the agents in the model; however, this result is not supported by Slobodyan and Wouters, (2012a).

[22]The initial beliefs for this parameter are 0.40; however, as a robustness check, I also consider a larger initial belief of 0.60, resulting in no change in the previously obtained results.

[23]Primiceri (2006) proposes that $\hat{c_2}$'s true value is 1.

[24]Potential misperceptions about the trend of output were captured by the intercept in the output equation in the learning rule.

[25]He provides evidence from the Economic Report of the President (EROP hereafter) that supports policymakers' perceptions of their ability to influence real activity and not inflation, especially during this period.

[26]Further support to this finding can be found in Okun (1978), Pruitt (2010), and the EROP from the proposed dates.

[27]In order to understand what is the true value of this trade-off I refer to Carboni and Ellison (2010). They perform an investigation on the Fed's evolving beliefs that matches not only inflation outcomes but also to Greenbook forecasts. The results are striking in the sense that even when conditioning on Greenbook forecasts, inflation outcomes are the result of a large perceived costs of disinflating that prevented the Federal Reserve from bringing inflation down.

[28]The combination of price and wage responses is the simple sum of the price and wage inflation coefficients, Best (2015) shows that the sum of these two coefficients determines the determinacy and learnability properties of the model. Moreover, Erceg, Henderson and Levin (2000) results suggest that the combination of both coefficients have important implications for social welfare.

[29] Ang et al. (2011) present a model in which the short rate follows a version of the Taylor (1993) rule where the coefficients on inflation and output can vary over time. They find that monetary policy loading on inflation, but not output, changed substantially over the past 50 years. In a previous version (Ang et al. (2009)), they find significantly more variation in the output gap loading when the term structure information included in their model is ignored.

[30]The time-varying responses of inflation and the output gap generally move in opposite directions; this conclusion follows from the fact that these coefficients are derived using policy preference parameters, and intuitively, reducing the volatility of one variable in the policy frontier would imply increasing the volatility of another variable (see Debortoli and Nunez, 2014).

[31]Results also show that after 1965 there was a decrease in the time-varying output gap coefficient concurrent with an increase in the time-varying inflation coefficient. Previous estimations start after 1970, or pay little attention to this episode. However, some narrative evidence (RR [1989], [2002]) is available about the prevailing policy stance and policymakers' beliefs. RR (2002) interpret that there is indication that between 1966 and 1967 the Fed increased its response to the inflation rate to prevent outward shifts in aggregate demand; that policy quickly but briefly turned into more than an attempt to offset expected increases in aggregate demand. In terms of policymakers' beliefs

about how the economy functions, RR (1989) find that (i) during the 1960s, policymakers had an optimistic view of inflation and output, and they attributed inflation increases to idiosyncratic factors, and (ii) their main concern was that inflation would continue, not that it would increase.

[32]Plots of time-varying policy responses to the output gap, inflation, and the lagged interest rate, fixed at the policy preference parameters estimated for the pre-1979 period and for the post-1979 period are available upon request.

[33]The choice of initial beliefs follows Slobodyan and Wouters (2012b).

[34]Figures for the beliefs present under these counterfactual experiments are available upon request.

[35]Owyang and Ramey (2004), OR hereafter, finds that policy preference switches occurred more than once during the sample period. In particular, they find that policy displayed three "dove regimes"–late 1960s, mid-1970s, and an interval around 1980–, in which policymakers more readily accommodated increases in the natural rate. Of note is that the model estimated here differs from OR's in important ways. In light of these differences, I also estimate the model allowing for several regime switches that follow the Romers' dates. RR (1989) and (1994) identify four dates—December 1968, April 1974, August 1978, and October 1979—that mark the beginning of policy tightening (Regime 1). I find that the fit of the OR and RR models to the data is considerably worst compared with all other specifications described; parameter values are available upon request. The estimation of endogenous policy regime switches in this setting is an interesting avenue of future research.

[36]In fact, under all alternative specifications that consider a change in gain—*Gains*, *Gains and SDs 1979*, *Gains and SDs 1984*, and *All*—the results point to a decrease in the speed of policymakers' learning about the structure of the economy in 1979. Allowing for a potential change in the gain improves the fit of the model to the data; therefore I consider this characteristic in the following two sets of models.

[37]Table B.1 in the Appendix presents parameter values

[38]Tables B.2 and B.3 in the Appendix present results for *SDs 1984*, and *All*. *Gains and SDs 1984* is the benchmark model.

[39]Parameter results are presented in the Appendix table $B.4$

References

[1] Altig, David, Lawrence Christiano, Martin Eichenbaum, and Jesper Linde (2011) Firm-specific capital, nominal rigidities and the business cycle. *Review of Economic Dynamics* 14(2), 225-247.

[2] An, Sungbae and Frank Schorfheide (2007) Bayesian analysis of DSGE models. *Econometric Reviews* 26(2-4), 113-172.

[3] Ang, Andrew, Jean Boivin, Sen Dong, and Rudy Loo-Kung (2011) Monetary policy shifts and the term structure. *Review of Economic Studies* 78(2), 429-457.

[4] Bernanke, Ben S. (2004) The Great Moderation. Remarks by Governor Ben S. Bernanke at the meetings of the Eastern Economic Association, Washington, DC, February 20, 2004.

[5] Best, Gabriela (2015) A New Keynesian Model with Staggered Price and Wage Setting under Learning. *Journal of Economic Dynamics and Control* 57, 96-111.

[6] Bianchi, Francesco and Leonardo Melosi (2012) Inflationary sentiments and monetary policy communication. Mimeo, Duke University.

[7] Boivin, Jean (2006) Has U.S. monetary policy changed? Evidence from drifting coefficients and real-time data. *Journal of Money, Credit and Banking* 38(5), 1149-1173.

[8] Brainard, William (1967) Uncertainty and the effectiveness of policy. *American Economic Review* 57, 411-425.

[9] Carboni, Giacomo and Martin Ellison (2009) The Great Inflation and the Greenbook. *Journal of Monetary Economics* 56(6), 831-841.

[10] Cecchetti, Stephen G., Peter Hooper, Bruce Kasman, Kermit L. Schoenholtz, and Mark W. Watson (2007) Understanding the evolving inflation process. U.S. Monetary Policy Forum 2007, February.

[11] Chib, Siddhartha and Edward Greenberg (1995) Understanding the Metropolis-Hastings algorithm. *American Statistician* 49(4), 327-335.

[12] Christiano, Larry, Martin S. Eichenbaum, and Charles Evans (1999) Monetary policy shocks: what have we learned and to what end? *Handbook of Macroeconomics*, vol. 1A.ed. In John Taylor John and Michael Woodford (eds.), 65-148 Elsevier.

[13] Christiano, Larry, Martin S. Eichenbaum, and Charles Evans (2005) Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy* 113, 1-45.

[14] Cogley, Timothy, and Thomas Sargent (2005) Drifts and volatilities: Monetary policies and outcomes in the post WWII U.S. *Review of Economic Dynamics* 8, 262-302.

[15] Cogley, Timothy, Giorgio E. Primiceri, and Thomas J. Sargent (2010) Inflation-Gap persistence in the US. *American Economic Journal: Macroeconomics* 2(1), 43-69.

[16] Cukierman, Alex (1989) Why does the Fed smooth interest rates? In Belgonia M. (ed.), *Monetary Policy on the 75th Anniversary of the Federal Reserve System*. Boston, MA: Kluwer Academica Press.

[17] De Long, Brad (1997) America's only peacetime inflation: the 1970s. In Romer C., Romer D. (Eds.), Reducing Inflation. Chicago: IL University of Chicago Press.

[18] Debortoli, Davide and Ricardo Nunes (2014) Monetary regime switches and central bank preferences. *Journal of Money, Credit and Banking* 46(8), 1591-1626.

[19] Dennis, Richard (2006) The policy preferences of the US Federal Reserve. *Journal of Applied Econometrics* 21, 55-77.

[20] Duffy, John and Engle-Warnick, Jim (2006) Multiple regimes in U.S. monetary policy? A nonparametric approach. *Journal of Money, Credit and Banking* 38(5), 1363-1377.

[21] Erceg, Christopher, Dale W. Henderson, and Andrew T. Levin (2000) Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics* 46, 281-313.

[22] Fernandez-Villaverde, Jesus, and Juan Rubio-Ramirez (2007) Estimating macroeconomic models: A Likelihood Approach. *Review of Economic Studies* 74(4), 1059-1087.

[23] Justiniano, Alejandro and Giorgio E. Primiceri (2008) The time-varying volatility of macroeconomic fluctuations. *American Economic Review* 98(3), 604-641.

[24] Kim, Chang-Jin and Charles R. Nelson, (1999) Has the U.S. economy become more stable? A Bayesian approach based on a Markov-switching model of the business cycle. *Review of Economics and Statistics* 81(4), 608-616.

[25] Kim, Chang-Jin and Charles R. Nelson (2006) Estimation of a forward-looking monetary policy rule: a time-varying parameter model using ex post data. *Journal of Monetary Economics* 53(8), 1949-1966.

[26] Giannoni Marc, and Michael Woodford (2003) Optimal inflation-targeting rules. In Ben S. Bernanke B.S and Michael Woodford (eds.), Inflation Targeting. Chicago: University of Chicago Press.

[27] Kreps, David, (1998) Anticipated utility and dynamic choice. In Donald P. Jacobs, Ehud Kalai, and Morton I. Kamien, (eds.), Frontiers of Research in Economic Theory, Cambridge University Press, 1998.

[28] Lubik, Thomas and Frank Schorfheide (2004) Testing for indeterminacy: an application to U.S. monetary policy. *American Economic Review* 94(1), 190-219.

[29] Marcet, Albert, and Juan P. Nicolini (2003) Recurrent hyperinflations and learning. *American Economic Review* 93(5), 1476-1498.

[30] McConnell, Margaret M. and Gabriel Perez-Quiros (2000) Output fluctuations in the United States: what has changed since the early 1980s? *American Economic Review* 90, 1464-1476.

[31] Milani, Fabio (2007) Expectations, learning and macroeconomic persistence. *Journal of Monetary Economics* 54, 2065-2082.

[32] Milani, Fabio (2011) Expectations shocks and learning as drivers of the business cycle. *Economic Journal*, 121, 379-401.

[33] Milani, Fabio (2012) The Effects of monetary policy "news" and "surprises." *Journal of Money, Credit and Banking* 44, 1667-1692.

[34] Milani, Fabio (2014) Learning and time-varying macroeconomic volatility. *Journal of Economic Dynamics and Control* 47, 94-114.

[35] Nelson, Edward. (2005). The Great Inflation of the seventies: What really happened? *Advances in Macroeconomics* 5(1), Article 3.

[36] Okun, Arthur M. (1978) Efficient disinflationary policies. *American Economic Review* 68, 348-352.

[37] Orphanides, Athanasios (2001) Monetary Policy Rules, Macroeconomic stability and inflation: A view from the trenches. *Journal of Money, Credit and Banking* 36(2), 151-175.

[38] Orphanides, Athanasios and John Williams (2005) The decline of activist stabilization policy: natural rate misperceptions, leaning and expectations. *Journal of Economic Dynamics and Control* 29, 1927-1950.

[39] Owyang, Michael and Garey Ramey (2004) Regime switching and monetary policy measurement. *Journal of Monetary Economics* 51, 1577-1597.

[40] Primiceri, Giorgio (2006) Why inflation rose and fell: policymakers beliefs and US postwar stabilization policy. *Quarterly Journal of Economics* 121, 867-890.

[41] Pruitt, Seth (2010) Uncertainty over models and data: The rise and fall of American inflation. *Journal of Money, Credit and Banking* 44(2-3), 341-365

[42] Romer, Christina D. and David H. Romer (1989) Does monetary policy matter? A new test in the spirit of Friedman and Schwartz. NBER Chapters, in: NBER Macroeconomics Annual 1989 4, 121-184.

[43] Romer, Christina D. and David H. Romer (1994) What ends recessions? NBER Chapters, in: NBER Macroeconomics Annual 1994 9, 13-80.

[44] Romer, Christina D. and David Romer (2002) The evolution of economics understanding and postwar stabilization policy. Proceedings - Economic Policy Symposium - Jackson Hole, Federal Reserve Bank of Kansas City, pages 11-78.

[45] Salemi, Michael K (1995) Revealed preferences of the Federal Reserve: using inverse control theory to interpret the policy equation of a vector autoregression. *Journal of Business and Economics Statistics* 13, 419-433.

[46] Sargent, Thomas (1987) *Dynamic macroeconomic theory*. Cambridge, MA: Harvard University Press.

[47] Sargent, Thomas (1999) The Conquest of American Inflation. Princeton, NJ: Princeton University Press.

[48] Sargent, Thomas, Noah Williams, and Tao Zha (2006) Shocks and government beliefs: the rise and fall of American inflation, *American Economic Review*, 6(4), 1193-1224.

[49] Sims, Christopher (2002) Solving linear rational expectations models. Mimeo, Princeton University.

[50] Stock H. James and Mark W. Watson (2003) Has the business cycle changed and why? NBER Chapters, in: NBER Macroeconomics Annual 2002 17, 159-230.

[51] Slobodyan, Sergey and Raf Wouters (2012a) Learning in a medium-scale DSGE Model with expectations based on small forecasting models. *American Economic Journal: Macroeconomics* 4(2), 65-101.

[52] Slobodyan, Sergey and Raf Wouters (2012b) Learning in an estimated medium-scale DSGE model. *Journal of Economic Dynamics and Control* 36(1), 26-46.

[53] Smets, Frank and Raf Wouters (2003) An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association* 1(5), 1123-1175.

[54] Smets, Frank, and Raf Wouters (2007) Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review* 97, 586-606.

[55] Taylor, John (1993) Discretion versus policy rules in practice. Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

[56] Woodford, Michael (2003) Interest and Prices: Foundations of a Theory of Monetary Policy. Princeton, NJ: Princeton University Press.

Tables

Table 1: *Prior Distributions*

Description	Name	Density	Mean	SD	95% Prior Probability Interval
IES	φ	Gamma	1.00	0.50	[0.27,2.19]
Habit formation	η	Beta	0.70	0.20	[0.25,0.98]
Function price stick.	ξ_p	Normal	0.01	0.01	[0.00,0.03]
H. econ. inc. price	ω_p	Gamma	0.89	0.40	[0.28,1.83]
H. econ. inc. wage	ω_w	Gamma	0.89	0.40	[0.28,1.83]
Infl. index price	γ_p	Beta	0.70	0.17	[0.32,0.96]
Infl. index wage	γ_w	Beta	0.70	0.17	[0.32,0.96]
Weight x	λ_x	Gamma	0.30	0.25	[0.02,0.95]
Weight π^w	λ_w	Gamma	0.30	0.25	[0.02,0.95]
Weight int. smooth.	λ_i	Gamma	6.25	4.27	[0.39,13.5]
Autoregr. dem.	ρ_r	Beta	0.50	0.20	[0.13,0.87]
Autoregr. sup.	ρ_p	Beta	0.70	0.10	[0.13,0.87]
Autoregr. wag.	ρ_w	Beta	0.50	0.20	[0.13,0.87]
MP shock	σ_{mp}	InvGamma	0.30	0.5	[0.06,1.15]
Demand shock	σ_r	InvGamma	0.50	0.51	[0.04,0.81]
Supply shock	σ_p	InvGamma	0.50	0.51	[0.04,0.82]
Wage shock	σ_w	InvGamma	0.15	0.51	[0.03,0.60]
Constant gain	$\mathbf{g}$	Gamma	0.03	0.02	[0.003,0.08]

Note: IES, intertemporal elasticity of substitution; Function of price stick., function of price stickiness; H. econ. inc. price, elasticity of the supply wage with respect to the quantity produced, holding fixed households' marginal utility of income; H. econ. inc. wage, elasticity of the marginal cost with respect to the quantity supplied at a given wage; Infl. index price, price inflation indexation; Infl. index wage, wage inflation indexation; Weight int. smooth., weight on the interest smoothing parameter; Autoregr., autoregressive parameter; MP, monetary policy.

Table 2: *Model comparisons*

Specifications	Description	Log marginal likelihood	Bayes' Factor vs. μ_1(L)
μ_1(L)	Break policy preference (1979)	-89.96	exp[-77.16]
μ_2(L)	Policy preference (full sample)	-136.78	exp[-123.96]
Case 1979			
Gains(L)	Break in the gain (1979)	-88.15	exp[-76.35]
SDs 1979(L)	Break in the SDs (1979)	-60.18	exp[-47.38]
Gains and SDs 1979(L)	Break in the gain and SDs (1979)	-66.75	exp[-53.95]
Case 1984			
SDs 1984(L)	Break in the SDs (1984)	-58.03	exp[-45.23]
Gain and SDs 1984(L)	Break in the gain (1979) and SDs (1984)	-12.80	1
All(L)	Break in all structural par. (1979)	-23.19	exp[-10.38]
	Break in the gain (1979) and SDs (1984)		
μ_1 with VAR(2)		-537.780	exp[-524.980]

Note: Log marginal likelihoods are computed using Geweke's modified harmonic mean approximation.

Table 3: *Posterior Estimates*

		Gains and SDs 1984 **Benchmark**	
Description	Parameter	Mean	95% P. I.
IES	φ	3.474	[2.118,4.947]
Habit formation	η	0.119	[0.029,0.246]
Function price stick.	ξ_p	0.003	[0.002,0.005]
H. econ. inc. price	ω_p	1.487	[1.157,1.827]
H. econ. inc. wage	ω_w	0.665	[0.220,1.193]
Infl. index price	γ_p	0.190	[0.070,0.324]
Infl. index wage	γ_w	0.552	[0.244,0.849]
Weight x	$\lambda_{x,pre-1979}$	1.034	[0.987,1.074]
Weight π^w	$\lambda_{w,pre-1979}$	0.262	[0.152,0.308]
Weight int.smooth.	$\lambda_{i,pre-1979}$	0.210	[0.036,0.476]
Weight x	$\lambda_{x,post-1979}$	0.150	[0.122,0.191]
Weight π^w	$\lambda_{w,post-1979}$	1.100	[0.337,1.764]
Weight int.smooth.	$\lambda_{i,post-1979}$	0.140	[0.019,0.396]
Autoregr. dem.	ρ_r	0.866	[0.820,0.908]
Autoregr. sup.	ρ_p	0.453	[0.356,0.539]
Autoregr. wag.	ρ_w	0.990	[0.983,0.994]
MP shock	$\sigma_{mp,1979-1982}$	0.024	[0.013,0.034]
Demand shock	$\sigma_{r,pre-1984}$	0.833	[0.609,1.115]
Supply shock	$\sigma_{p,pre-1984}$	0.313	[0.235,0.402]
Wage shock	$\sigma_{w,pre-1984}$	0.131	[0.080,0.190]
MP shock	$\sigma_{mp,o/w}$	0.002	[0.002,0.003]
Demand shock	$\sigma_{r,post-1984}$	0.350	[0.229,0.520]
Supply shock	$\sigma_{p,post-1984}$	0.172	[0.131,0.222]
Wage shock	$\sigma_{w,post-1984}$	0.233	[0.172,0.313]
Constant gain	$\mathbf{g}_{pre-1979}$	0.029	[0.029,0.030]
Constant gain	$\mathbf{g}_{post-1979}$	0.006	[0.004,0.008]
Log marginal likelihood		-12.80	

Note: P.I., posterior probability interval.

Table 4: *Posterior Estimates*

		μ_1		μ_2		*Gain*	
Description	Parameter	Mean	95% P. I.	Mean	95% P. I.	Mean	95% P. I.
IES	φ	1.197	[0.738,1.896]	2.149	[1.512, 2.892]	3.364	[1.897,4.737]
Habit formation	η	0.164	[0.052,0.287]	0.115	[0.019,0.236]	0.415	[0.224,0.551]
Fcn. price stick.	ξ_p	0.103	[0.088,0.118]	0.024	[0.016,0.042]	0.074	[0.058,0.091]
H. econ. inc. price	ω_p	0.653	[0.531,0.804]	1.216	[1.066,1.406]	0.817	[0.617,1.066]
H. econ. inc. wage	ω_w	8.871	[5.255,11.207]	1.294	[0.713,1.835]	8.653	[5.082,11.970]
Infl. index price	γ_p	0.420	[0.307,0.523]	0.291	[0.116,0.488]	0.323	[0.212,0.457]
Infl. index wage	γ_w	0.975	[0.932,0.997]	0.939	[0.808,0.995]	0.968	[0.909,0.996]
Weight x	$\lambda_{x,All}$			0.039	[0.001,0.125]		
Weight π^w	$\lambda_{w,All}$			1.323	[0.676,2.214]		
Weight int. s.	$\lambda_{i,All}$			0.168	[0.133,0.191]		
Weight x	$\lambda_{x,pre-1979}$	0.575	[0.432,0.741]			0.649	[0.497,0.876]
Weight π^w	$\lambda_{w,pre-1979}$	1.790	[1.175,2.283]			1.862	[1.359,2.278]
Weight int. s.	$\lambda_{i,pre-1979}$	0.280	[0.201,0.330]			0.100	[0.015,0.132]
Weight x	$\lambda_{x,post-1979}$	0.006	[0.0002,0.017]			0.018	[0.002,0.043]
Weight π^w	$\lambda_{w,post-1979}$	0.552	[0.457,0.687]			0.706	[0.517,0.894]
Weight int. s.	$\lambda_{i,post-1979}$	0.094	[0.087,0.099]			0.008	[0.001,0.014]
Autoregr. dem.	ρ_r	0.242	[0.045,0.458]	0.528	[0.417,0.612]	0.829	[0.768,0.885]
Autoregr. sup.	ρ_p	0.188	[0.111,0.261]	0.342	[0.235,0.448]	0.294	[0.199,0.397]
Autoregr. wag.	ρ_w	0.992	[0.990,0.995]	0.976	[0.959,0.988]	0.988	[0.979,0.993]
MP shock	σ_{mp}	0.001	[0.001,0.002]	0.002	[0.002,0.003]	0.002	[0.002,0.003]
Demand shock	σ_r	3.076	[2.758,3.494]	2.371	[2.024,2.689]	0.467	[0.339,0.644]
Supply shock	σ_p	0.605	[0.529,0.680]	0.346	[0.242,0.459]	0.478	[0.383,0.594]
Wage shock	σ_w	0.014	[0.011,0.016]	0.511	[0.332,0.781]	0.014	[0.011,0.017]
Gain	$\mathbf{g}$	0.018	[0.017,0.019]	0.010	[0.007,0.016]		
Gain	$\mathbf{g}_{pre-1979}$					0.018	[0.017,0.019]
Gain	$\mathbf{g}_{post-1979}$					0.006	[0.003,0.008]
Log marginal likelihood		-89.96		-136.78		-88.15	

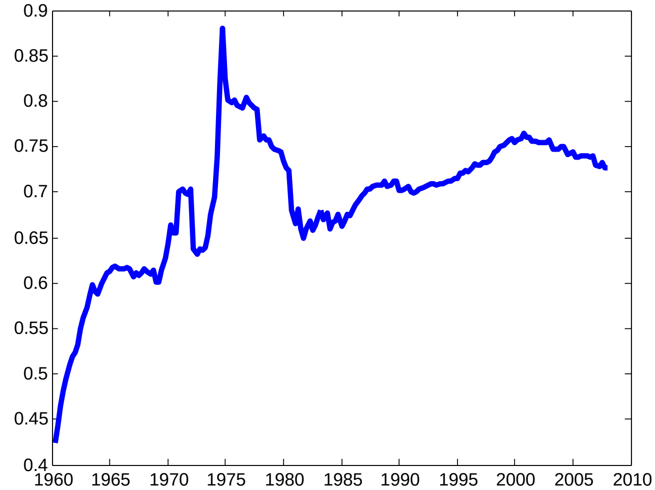

Figure 1: *Policymakers' beliefs about the persistence of inflation in the Phillips Curve.*

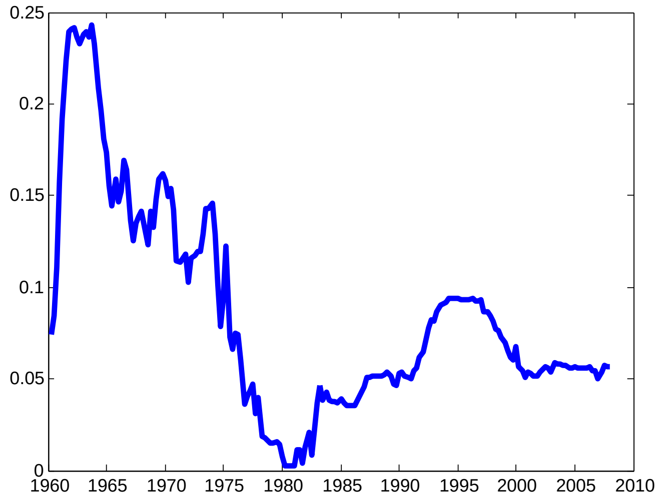

Figure 2: *Policymakers' beliefs about the slope of the Phillips Curve.*

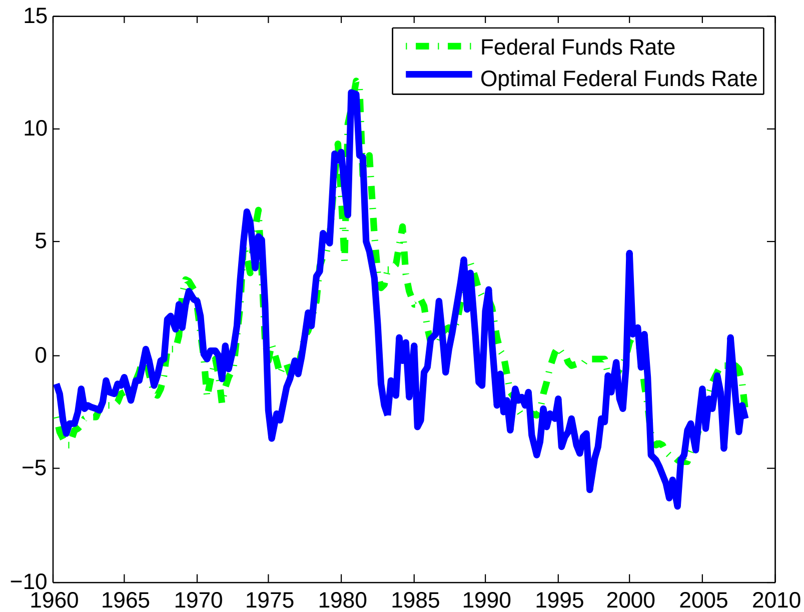

Figure 3: *Federal funds rate and estimated optimal monetary policy variable: benchmark model.*

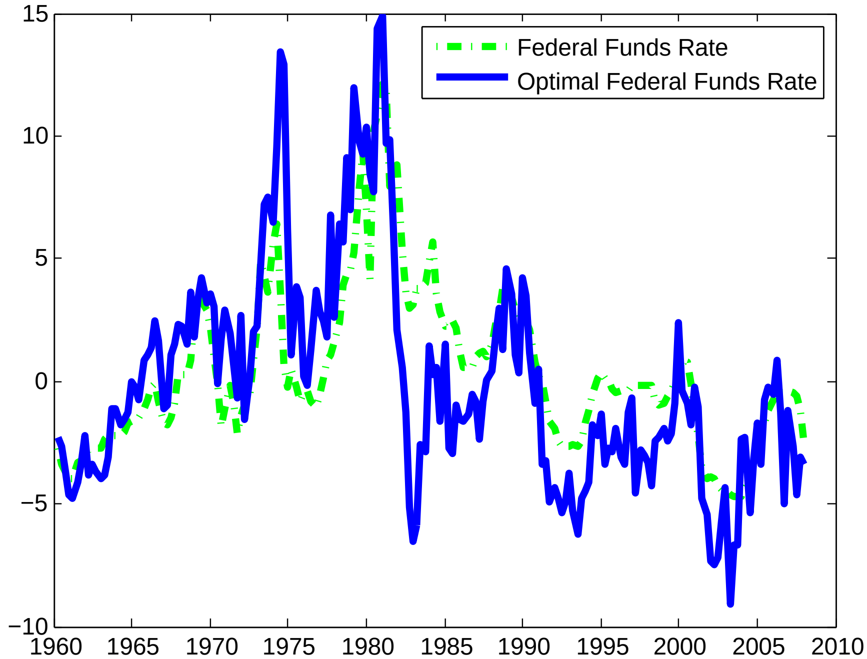

Figure 4: *Federal funds rate and estimated optimal monetary policy variable: no regime change model* μ_2.

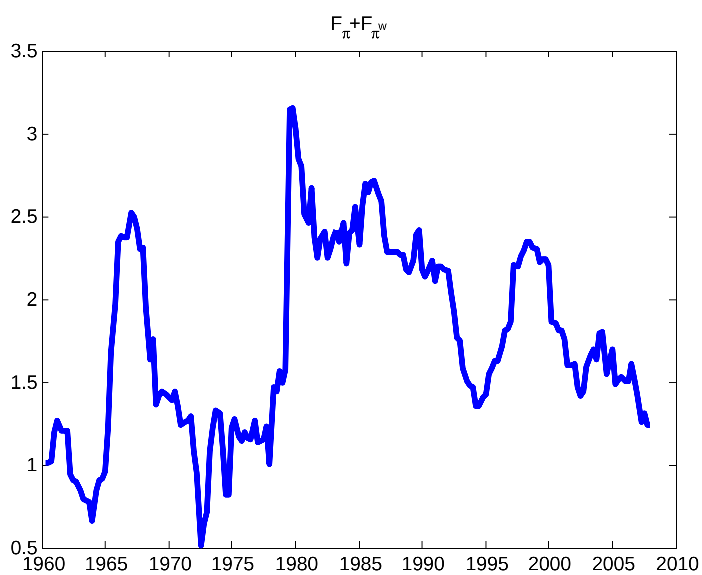

Figure 5: *Price and wage inflation in the model's time-varying policy reaction function.*

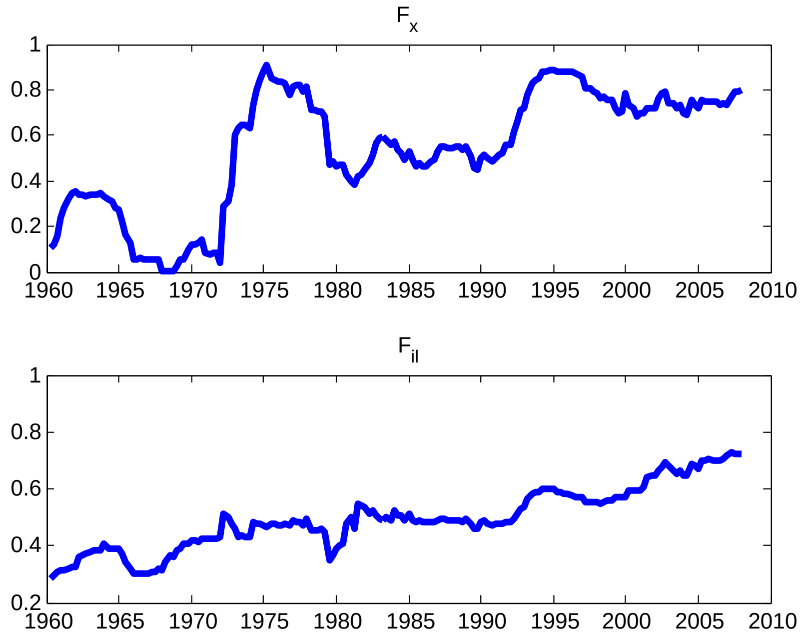

Figure 6: *(a) Output gap (top) and (b) lagged interest rate responses (bottom) in the model's time-varying policy reaction function.*

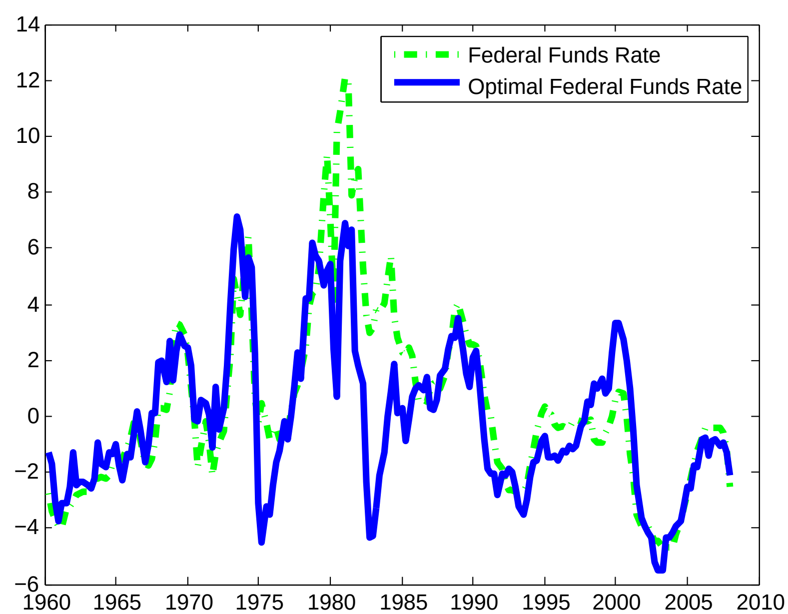

Figure 7: *Federal funds rate and estimated optimal monetary policy variable under policy preference parameters fixed to pre-1979 policy preference parameter.*

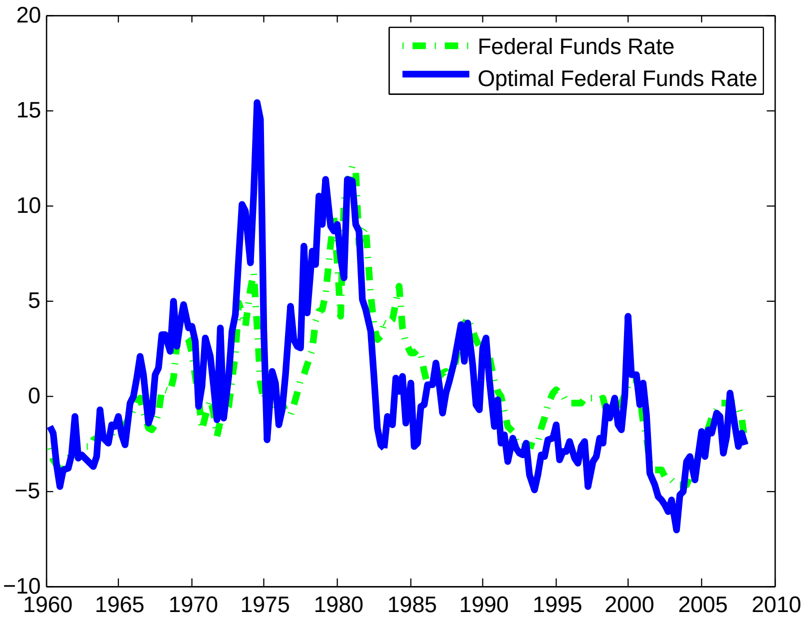

Figure 8: *Federal funds rate and estimated optimal monetary policy variable under policy preference parameters fixed to post-1979 policy preference parameter.*

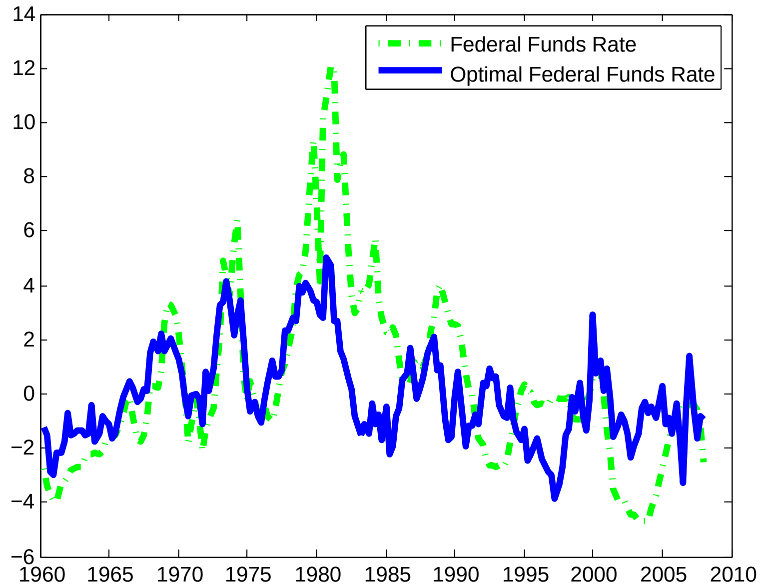

Figure 9: *Federal funds rate and estimated optimal monetary policy variable benchmark model without learning.*

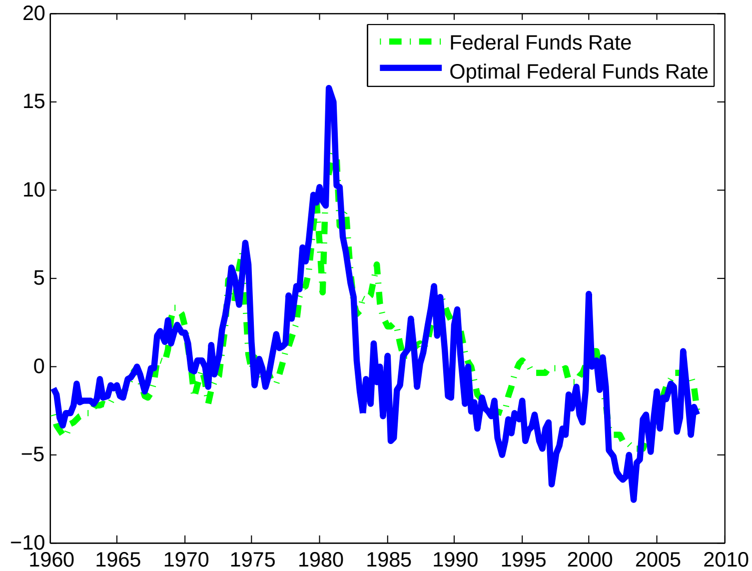

Figure 10: *Federal funds rate and estimated policy variable for post-1979 gain.*

APPENDIX A

State Space Form and Optimal Policy

The optimization constraints have the following state-space representation.

$$z_{t+1} = C_t + A_t z_t + B_t i_t + e_{t+1} \tag{A.1}$$

where $z_t = [x_t, x_{t-1}, \pi_t, \pi_{t-1}, \pi_{t-2}, W_t, W_{t-1}, W_{t-2}, i_{t-1}, i_{t-2}]'$ is the state vector, $e_{t+1} = [e^y_{t+1}, 0, e^\pi_{t+1}, 0, 0, e^w_{t+1}, 0, 0, 0, 0]'$ is the shock vector, and i_t is the control variable, and the matrices in the state-space form are $C = \begin{bmatrix} \hat{c}_y & 0 & \hat{c}_\pi & 0 & 0 & \hat{c}_w & 0 & 0 & 0 & 0 \end{bmatrix}$, $B = \begin{bmatrix} \hat{b}_4 & 0 & \hat{c}_4 & 0 & 0 & \hat{d}_4 & 0 & 0 & 1 & 0 \end{bmatrix}$,

and $A = \begin{bmatrix} \hat{b}_1 & 0 & \hat{b}_2 & 0 & 0 & \hat{b}_3 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hat{c}_1 & 0 & \hat{c}_2 & 0 & 0 & \hat{c}_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hat{d}_1 & 0 & \hat{d}_2 & 0 & 0 & \hat{d}_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$.

The quadratic loss function is characterized in terms of the state and control vectors in the following form:

$$E_t \left\{ \sum_{j=0}^{\infty} \beta^j [(z_{t+j})' Q (z_{t+j}) + (i_{t+j})' R (i_{t+j}) + 2 (z_{t+j})' U (i_{t+j})] \right\} \tag{A.2}$$

In this representation, the matrices Q,U, and R contain the policy preference parameters represented as below:

$$Q = \begin{bmatrix} \lambda_x & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & (1+\lambda_w) & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 2\lambda_w & \lambda_w & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -2\lambda_w & -2\lambda_w & 0 & 0 & \lambda_w & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda_i & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$R = \begin{bmatrix} \lambda_i \end{bmatrix} U' = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\lambda_i & 0 \end{bmatrix}$$

Following Sargent (1987) the solution to this stochastic linear optimal regulator problem is the optimal policy rule:

$$i_t = F(\hat{\phi}_t) z_t, \tag{A.3}$$

where

$$F = -(R + \beta BPB)^{-1}(V + \beta B'PA) \tag{A.4}$$

$$P = Q + \beta A'PA - (\beta A'PB + U')(R + \beta B'PB)^{-1}(\beta B'PA + U). \tag{A.5}$$

Eq. (63) is a matrix Riccati equation. To obtain a solution for P it was iterated to convergence. i_t will be implemented every period. The solution to the problem is a function of the parameters from the VAR estimated by the policymakers every period $\hat{\phi}_t = [\hat{c}_y, \hat{b}_1, \hat{b}_2, \hat{b}_3, \hat{b}_4, \hat{c}_\pi, \hat{c}_1, \hat{c}_2, \hat{c}_3, \hat{c}_4 \hat{c}_w, \hat{d}_1, \hat{d}_2, \hat{d}_3, \hat{d}_4]'$; i_t will also be determined by the pertinent state variables. The value for i_t will embed the policymakers' beliefs about the state of the economy.

The policy solution's structural form representation is the equation

$$i_t = F_x x_t + F_\pi \pi_t + F_w \pi_t^w + F_{il} i_{t-1}^f. \quad \text{(A.6)}$$

Furthermore, i_t will be used to estimate the parameters of the model of the economy including the preference parameters.

APPENDIX B

Additional Tables

Table B.1: *Posterior Estimates*

		SDs 1979		Gains and SDs 1979	
Description	Parameter	Mean	95% P. I.	Mean	95% P.I.
IES	φ	6.052	[4.650, 8.024]	1.956	[1.330,2.579]
Habit formation	η	0.056	[0.013,0.122]	0.186	[0.062,0.311]
Function price stick.	ξ_p	0.025	[0.013,0.038]	0.056	[0.043,0.070]
H. econ. inc. price	ω_p	0.241	[0.089,0.507]	0.093	[0.029,0.221]
H. econ. inc. wage	ω_w	2.699	[0.883,5.776]	0.643	[0.246,1.192]
Infl. index price	γ_p	0.100	[0.026,0.212]	0.125	[0.038,0.238]
Infl. index wage	γ_w	0.954	[0.869,0.995]	0.952	[0.894,0.991]
Weight x	$\lambda_{x,pre-1979}$	1.041	[0.417,1.731]	0.681	[0.605,0.819]
Weight π^w	$\lambda_{w,pre-1979}$	0.061	[0.004,0.200]	1.660	[0.959,2.299]
Weight int.smooth.	$\lambda_{i,pre-1979}$	0.100	[0.011,0.144]	0.169	[0.031,0.396]
Weight x	$\lambda_{x,post-1979}$	0.018	[0.009,0.031]	0.454	[0.411,0.496]
Weight π^w	$\lambda_{w,post-1979}$	0.865	[0.635,1.104]	0.251	[0.089,0.429]
Weight int.smooth.	$\lambda_{i,post-1979}$	0.020	[0.003,0.038]	0.007	[0.000,0.077]
Autoregr. dem.	ρ_r	0.890	[0.847,0.926]		
Autoregr. sup.	ρ_p	0.417	[0.333,0.491]		
Autoregr. wag.	ρ_w	0.937	[0.916,0.960]		
Autoregr. dem.	$\rho_{r,pre-1979}$			0.795	[0.721,0.854]
Autoregr. sup.	$\rho_{p,pre-1979}$			0.401	[0.273,0.521]
Autoregr. wag.	$\rho_{w,pre-1979}$			0.104	[0.021,0.235]
MP shock	$\sigma_{mp,pre-1979}$	0.005	[0.004,0.006]	0.005	[0.004,0.007]
Demand shock	$\sigma_{r,pre-1979}$	0.223	[0.177,0.279]	0.649	[0.478,0.879]
Supply Shock	$\sigma_{p,pre-1979}$	0.004	[0.003,0.005]	0.175	[0.127,0.234]
Wage Shock	$\sigma_{w,pre-1979}$	0.210	[0.157,0.268]	0.038	[0.029,0.049]
Autoregr. dem.	$\rho_{r,post-1979}$			0.912	[0.863,0.954]
Autoregr. sup.	$\rho_{p,post-1979}$			0.407	[0.317,0.491]
Autoregr. wag.	$\rho_{w,post-1979}$			0.913	[0.888,0.930]
MP shock	$\sigma_{mp,post-1979}$	0.381	[0.248,0.546]	0.016	[0.003,0.163]
Demand shock	$\sigma_{r,post-1979}$	0.021	[0.016,0.027]	0.820	[0.562,1.126]
Supply shock	$\sigma_{p,post-1979}$	0.2496	[0.154,0.378]	0.236	[0.179,0.312]
Wage shock	$\sigma_{w,post-1979}$	0.569	[0.445,0.695]	0.643	[0.550,0.752]
Gain	$\mathbf{g}$	0.018	[0.017,0.019]		
Gain	$\mathbf{g}_{pre-1979}$			0.020	[0.019,0.021]
Gain	$\mathbf{g}_{post-1979}$			0.019	[0.018,0.019]
Log marginal likelihood		-60.18		-66.75	

Table B.2: *Posterior Estimates*

		SDs 1984	
Description	Parameter	Mean	95% P. I.
IES	φ	3.115	[2.025,4.286]
Habit formation	η	0.118	[0.032,0.221]
Function price stick.	ξ_p	0.002	[0.001,0.005]
H. econ. inc. price	ω_p	0.897	[0.447,1.399]
H. econ. inc. wage	ω_w	0.898	[0.285,1.569]
Infl. index price	γ_p	0.209	[0.097,0.331]
Infl. index wage	γ_w	0.865	[0.750,0.983]
Weight x	$\lambda_{x,pre-1979}$	2.566	[1.937,3.052]
Weight π^w	$\lambda_{w,pre-1979}$	6.471	[5.232,7.309]
Weight int.smooth.	$\lambda_{i,pre-1979}$	0.099	[0.098,0.099]
Weight x	$\lambda_{x,post-1979}$	0.075	[0.060,0.092]
Weight π^w	$\lambda_{w,post-1979}$	0.659	[0.594,0.728]
Weight int.smooth.	$\lambda_{i,post-1979}$	0.042	[0.008,0.090]
Autoregr. dem.	ρ_r	0.886	[0.852,0.917]
Autoregr. sup.	ρ_p	0.377	[0.268,0.466]
Autoregr. wag.	ρ_w	0.986	[0.980,0.991]
MP shock	$\sigma_{mp,1979-1982}$	0.025	[0.015,0.035]
Demand shock	$\sigma_{r,pre-1984}$	0.208	[0.141,0.299]
Supply shock	$\sigma_{p,pre-1984}$	0.413	[0.346,0.487]
Wage shock	$\sigma_{w,pre-1984}$	0.132	[0.096,0.173]
MP shock	$\sigma_{mp,o/w}$	0.004	[0.004,0.005]
Demand shock	$\sigma_{r,post-1984}$	0.092	[0.062,0.134]
Supply shock	$\sigma_{p,post-1984}$	0.184	[0.141,0.235]
Wage shock	$\sigma_{w,post-1984}$	0.277	[0.219,0.365]
Constant Gain	$\mathbf{g}$	0.006	[0.004,0.008]
Log marginal likelihood		-58.03	

Table B.3: *Posterior Estimates*

		All			
Parameter	Mean	95% P. I.	Parameter	Mean	95% P. I.
$\varphi_{pre-1979}$	3.810	[2.188,5.755]	$\varphi_{post-1979}$	1.179	[0.312,2.313]
$\eta_{pre-1979}$	0.097	[0.022,0.191]	$\eta_{post-1979}$	0.364	[0.150,0.733]
$\xi_{p,pre-1979}$	0.006	[0.003,0.013]	$\xi_{p,post-1979}$	0.001	[0.000,0.003]
$\omega_{p,pre-1979}$	1.869	[1.014,3.039]	$\omega_{p,post-1979}$	0.992	[0.609,1.385]
$\omega_{w,pre-1979}$	0.714	[0.228,1.292]	$\omega_{w,post-1979}$	0.866	[0.265,1.718]
$\gamma_{p,pre-1979}$	0.339	[0.163,0.522]	$\gamma_{p,post-1979}$	0.186	[0.075,0.324]
$\gamma_{w,pre-1979}$	0.730	[0.517,0.939]	$\gamma_{w,post-1979}$	0.726	[0.393,0.954]
$\lambda_{x,pre-1979}$	0.797	[0.788,0.802]	$\lambda_{x,post-1979}$	0.349	[0.164,0.489]
$\lambda_{w,pre-1979}$	0.050	[0.037,0.075]	$\lambda_{w,post-1979}$	0.318	[0.108,0.622]
$\lambda_{i,pre-1979}$	0.123	[0.023,0.266]	$\lambda_{i,post-1979}$	0.080	[0.011,0.223]
$\rho_{r,pre-1979}$	0.800	[0.728,0.866]	$\rho_{r,post-1984}$	0.900	[0.853,0.941]
$\rho_{p,pre-1979}$	0.430	[0.277,0.549]	$\rho_{p,post-1984}$	0.429	[0.322,0.518]
$\rho_{w,pre-1979}$	0.984	[0.968,0.993]	$\rho_{w,post-1984}$	0.991	[0.984,0.996]
$\sigma_{mp,1979-1982}$	0.022	[0.016,0.029]	$\sigma_{mp,o/w}$	0.002	[0.002,0.003]
$\sigma_{r,pre-1984}$	1.338	[0.977,1.785]	$\sigma_{r,post-1984}$	0.696	[0.486,0.966]
$\sigma_{p,pre-1984}$	0.293	[0.220,0.382]	$\sigma_{p,post-1984}$	0.175	[0.135,0.226]
$\sigma_{w,pre-1984}$	0.168	[0.096,0.268]	$\sigma_{w,post-1984}$	0.223	[0.153,0.313]
$\mathbf{g}_{pre-1984}$	0.023	[0.021,0.024]	$\mathbf{g}_{post-1979}$	0.019	[0.019,0.019]
Log marginal likelihood		-23.19			

Additional Figures

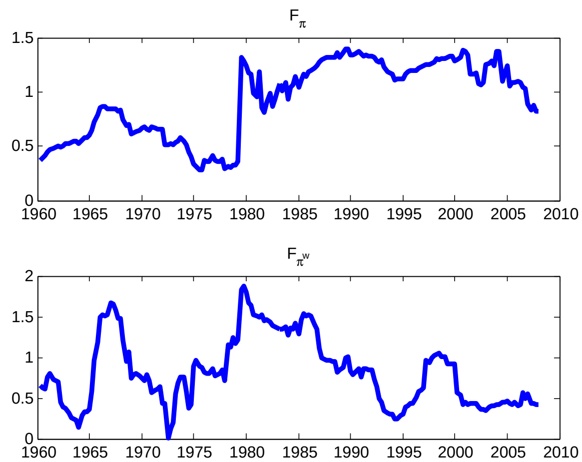

Figure B.1: *(a) Price inflation (top) and (b) wage inflation (bottom) responses in the model's time-varying policy reaction function*

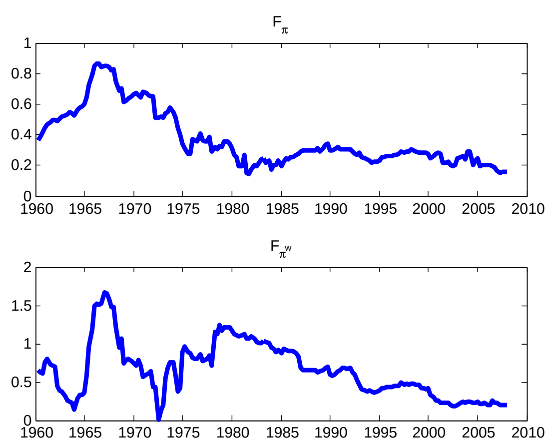

Figure B.2: *(a) Price inflation (top) and (b) wage inflation (bottom) responses fixed to pre-1979 policy preference parameters in the model's time-varying policy reaction function*

Table B.4: *Posterior Estimates*

		μ_1 with 2 lags	
Description	Parameter	Mean	95% P. I.
IES	φ	2.012	[1.132,3.697]
Habit formation	η	0.282	[0.079,0.435]
Function price stick.	ξ_p	0.043	[0.029,0.058]
H. econ. inc. price	ω_p	0.706	[0.573,0.800]
H. econ. inc. wage	ω_w	9.436	[7.520,12.406]
Infl. index price	γ_p	0.254	[0.111,0.410]
Infl. index wage	γ_w	0.636	[0.424,0.797]
Weight x	$\lambda_{x,pre-1979}$	0.159	[0.113,0.212]
Weight π^w	$\lambda_{w,pre-1979}$	0.764	[0.418,1.093]
Weight int.smooth.	$\lambda_{i,pre-1979}$	0.118	[0.053,0.208]
Weight x	$\lambda_{x,post-1979}$	0.005	[0.001,0.009]
Weight π^w	$\lambda_{w,post-1979}$	1.009	[0.851,1.137]
Weight int.smooth.	$\lambda_{i,post-1979}$	0.100	[0.100,0.100]
Autoregr. dem.	ρ_r	0.876	[0.812,0.919]
Autoregr. sup.	ρ_p	0.347	[0.272,0.446]
Autoregr. wag.	ρ_w	0.993	[0.990,0.995]
MP shock	σ_{mp}	0.032	[0.026,0.037]
Demand shock	σ_r	0.203	[0.138,0.305]
Supply shock	σ_p	0.409	[0.346,0.469]
Wage shock	σ_w	0.028	[0.022,0.037]
Constant gain	$\mathbf{g}$	0.013	[0.013,0.018]
Log marginal likelihood		-537.78	

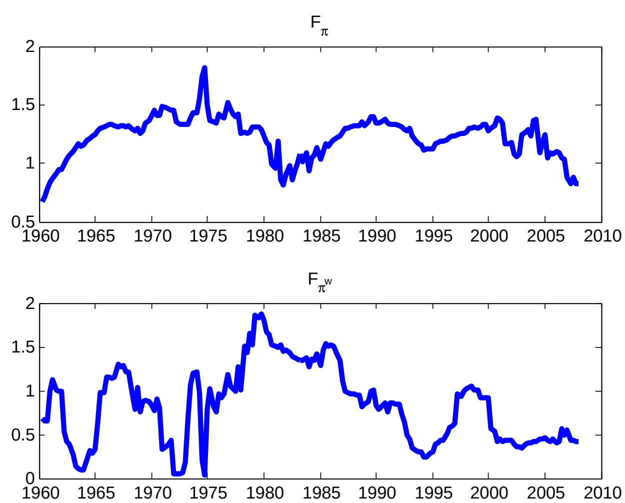

Figure B.3: *(a) Price inflation (top) and (b) wage inflation (bottom) responses fixed to post-1979 policy preference parameters in the model's time-varying policy reaction function*