Policy Preferences and Policymakers' Beliefs: The Great Inflation

Gabriela Best*
Missouri State University and University of California, Irvine

November 9, 2011

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 holds that policymakers shifted preferences towards inflation stabilization post 1979. An alternative explanation contends that the Federal Reserve held misperceptions about the economy. 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 both views combined, 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 illustrate the role played by monetary policy in propagating and ending the Great Inflation.

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

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

**Address for correspondence*: Missouri State University, Economics Department, 901 S. National Ave., Springfield, MO 65897. Phone 626-841-4035. *E-mail* GBest@MissouriState.edu. I especially thank Fabio Milani for his advice and help in many aspects of this project. I also thank Bill Branch, Edward Nelson, Michelle Garfinkel, Michael Owyang, Dale Poirier, Giorgio Primiceri, Davide Debortoli, Char Weise, Ricardo Reis, anonymous referee, and all seminar participants at the 2011 Midwest Macro Meetings, Federal Reserve Bank of St. Louis, University of California, Irvine and Missouri State University for important input into this paper. I also want to thank the Federal Reserve Bank of St. Louis for hosting me during part of this project and the Department of Economics and School of Social Sciences at the University of California, Irvine for financial support.

1. 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. There are a number of hypotheses on the causes: bad monetary policy, bad luck due to the sequence of shocks, lack of commitment to low inflation policies, an overly optimistic view of potential output and erroneous beliefs about the structure, or a change in policymakers' preferences towards inflation stabilization.[1] Cecchetti et al. (2007) argue that none of these factors fully explain the drastic and sudden disinflation process experienced in the United States in the 1980s. They acknowledge that deviations from potential output and policy learning contribute to the Great Inflation, but these factors are not sufficient to account for the whole phenomenon. Cecchetti et al. propose that a key factor in explaining the Great Inflation was a change in preferences towards output gap stabilization by officials at the Federal Reserve. This paper combines two potential approaches regarding how monetary policy might have played a role in the rise and fall of inflation in the United States during the 1970s and the 1980s.

One approach holds that monetary policymakers during the late 1960s and throughout the 1970s preferred stabilizing output, while after 1979 they preferred inflation stabilization. The notion that there was such a shift in *preferences* between the late 1960s and the appointment of Paul Volcker as chairman of the Federal Reserve finds support in De Long (1997). He argues that the Federal Reserve between the late 1960s to the late 1970s, with the Great Depression fresh in their memories, "lacked the mandate to fight inflation by inducing a significant recession," (De Long 1997 p. 273).

An alternative approach holds that the Federal Reserve misperceived the state of the economy and the transition equations for the economy. Such erroneous *beliefs* could induce policymakers to create excessive inflation that would be reversed once beliefs are aligned with outcomes via an adaptive *learning* process. The previous literature, including Romer and Romer (2002), Sargent (1999), and Primiceri (2006), has argued that misperceptions regarding the standard features of the U.S. economy (such as how to measure the natural rate of unemployment,

[1] An additional explanation to the Great Inflation was examined in Romer and Romer (2002) and Nelson (2005). The authors conclude that policymakers during the 1970s dabbled in non-standard policies to control inflation, such as price and wage controls, because they believed that inflation was impervious to slack.

or the existence of a Phillips curve and its coefficients) were important factors in the Great Inflation. In the models of Sargent (1999) and Primiceri (2006), policymakers learn about the parameters overtime, updating their beliefs through constant-gain learning (CGL).[2]

This paper studies the Great Inflation in a medium scale macroeconomic model that embeds both, a possible change in policymakers' preferences from the Great Inflation into the inflation stabilization era and changing beliefs, through learning, about the state of the economy. It is left to the data to disentangle whether a change in preferences contributed to the prolonged inflationary period, or if the episode was solely due to policymakers' beliefs. Specifically, this paper combines the policymakers' (potential) shift in preferences view of Cecchetti et al. (2007) and Dennis (2006), and the learning hypothesis in Primiceri (2006). By combining both elements, the learning hypothesis with the policymakers' shift in preferences, the empirical results illustrate the extent to which changes in the *perceived* inflation – output trade off or the *preferred* inflation – output trade off can help explain the Great Inflation.

In order to gauge to what extent these two hypotheses contribute to explain the Great Inflation I estimate a New Keynesian DSGE model that includes wage and price stickiness as the 'true model' of the economy. I assume that policymakers have imperfect information about the model of the economy and its parameters. Policymakers use historical data to learn the parameters over time, updating their beliefs through constant gain learning (CGL). Subsequently, policymakers solve the optimal control problem using beliefs derived from their model in order to formulate and implement a policy variable. The preference parameters and the coefficients of the 'true' model are jointly estimated using Bayesian methods.

One contribution of this paper is to use 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 periods pre- and post 1979, 1979 being the year that Paul Volcker was appointed Chairman of the Board of Governors of the Federal Reserve System. The change

[2]Primiceri associates the Great Inflation with the policymakers' belief that disinflation policy was very costly, view shared in Romer and Romer (2002), Cogley and Sargent (2005), Carboni and Ellison (2009) and Pruitt (2010). Primiceri concludes that a change in the perceived inflation-unemployment trade off was what put an end to the Great inflation.

in *preferences* or lack thereof between the two periods will be identified by the change in the weights of the central bank loss function. This approach builds on Dennis (2006) and Salemi (1995) who estimate parameters in the objective function jointly with parameters in the optimizing constraint using maximum likelihood methods. They conclude that the appointment of a different chairman of the Federal Reserve is consistent with policy regime changes or changes in policy preferences.

The empirical results of this paper show that policymakers' beliefs about the state of the economy, in addition to a change in policymakers' 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 do not react strongly enough to inflation during the Great Inflation because they perceived a downward biased estimate of the persistence of inflation that will revert to its mean value at any time. Moreover, the estimated coefficients of the policymakers' model indicated that they perceived an unfavorable trade off between the output gap and inflation for most of the 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.

More importantly, the empirical results show that there was a shift in preferences for stabilizing inflation and the output gap after Volcker's appointment as chairman of the Federal Reserve, even in the presence of policymakers learning about the structure of the economy. The weight that central bankers in this model put on stabilizing the output gap approaches zero in the post-1979 period. As a result, the central bankers' response to inflation increases considerably after 1979. In addition to these changes, there is a gradual but substantial increase in the interest smoothing parameter that peaks in the early 80's. Therefore, as pointed out in Cecchetti et al. (2007) even in the face of an overestimated sacrifice ratio, inflation proved so damaging that central bankers acted to disinflate. Therefore, a monetary policy regime change was important to observe large movements in the trend of inflation in the United States.[3]

[3]The change in preference hypothesis has been supported in papers that estimate the objective function of the Fed such as Dennis (2006) and in regime switching models such as Owyang et al. (2004). Owyang et al. 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

2. The Model

The following optimizing model is a DSGE model in the spirit of Erceg et al. (2000), Woodford (2003), Giannoni and Woodford (2005). This model includes internal habit persistence, wage stickiness, and inflation inertia, which have proven to improve the empirical properties of the model, giving more realism to the transmission mechanisms. [4]

In a standard New Keynesian model, nominal price rigidities give rise to the key frictions that makes monetary policy non-neutral. Recent work has shown that staggering of nominal wage contracts is important as well. Models that only consider sticky prices and not sticky wages have been criticized for producing "too sharp a real-wage decline in response to a tightening of monetary policy" as addressed in Christiano et al. (1999). The main result is that even with the decrease in sales, producers' profits increase. Furthermore, Christiano et al. (1999) analyze impulse responses to an unexpected interest rate reduction, and they finds a slightly pro-cyclical real wage movement. The explanation to this modest response of real wages is that there is slow wage adjustment to any given change in labor demand. This explanation validates wage stickiness as an important piece in explaining real effects of monetary policy. Erceg et al. (2002) extend the New Keynesian model to account for nominal wage inertia. In this model monopolistically competitive producers set prices in staggered wage contracts. Christiano et al. (2005), Altig et al. (2002) and Smets and Wouters (2002) conclude that impulse response functions after a monetary policy shock are best fit by the model with staggered wage contracts. The model's impulse response functions are close to the ones obtained by fitting a VAR, and the model best fits the humped shaped dynamics of output and real wage. Lastly, Christiano et al. (2001) conclude that wage stickiness and not price stickiness appears to be more important in explaining output and inflation dynamics.

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

intent to exert contractionary monetary policy to reduce inflation, thus supporting the view that there has been changes in policymakers' preferences, especially around 1979.

[4] Details on the model derivation are provided in the Appendix

the 1970s as in De Long (1997). He proposes that historically there had been a 1.5 percentage point gap between wage and price inflation in the 1950s and 1960s (wages always higher). Moreover, he compares the patterns of wage and price inflation and notices an ambiguity in the character of inflation in the 1970s. In prices, inflation rose after 1968, from 5 percent in 1968 to over 10 percent in 1981. In wages, inflation emerged by 1968, rising from 6.5 percent to a peak of a little more than 8 percent at the end of the 1970s. Thus, he suggests that while the "magnitude of the inflation control problem" changed between the late 1960s, when policymakers realized the problem, to 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. These issues make it relevant for the study of the Great Inflation to include wage and wage inflation into the model of the economy.

The structural equations that give the aggregate dynamics of output, price, and wage inflation consist of equations (1), (2), (3), (4), and (5) reproduced here for convenience. The demand block is represented by:

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

where

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

and $\varphi \equiv [(1-\eta\beta)\sigma]^{-1}$.

The supply side model is given by 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 the identity

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

Equation (1) is the log-linearized Euler equation. Equations (3) and (4) are Phillips curves for prices and wages. Equation (5) is an identity for the real wage ($w_t = \mathrm{W}_t/P_t$) expressed in logs and rearranged to provide a law of motion for the log of nominal wages. Here x_t represents the output gap, π_t and π_t^w are nominal price and wage inflation, w_t is the log of the real wage, w_t^n represents exogenous variation in the natural real wage, i_t denotes the monetary policy variable determined within the model, and E_t represents rational expectations. $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $\beta \in (0,1)$ is the household's discount factor, $0 \leq \eta \leq 1$ is the measure of habit persistence in consumption, and $0 \leq \gamma_p \leq 1$ and $0 \leq \gamma_w \leq 1$ represent the degree of indexation to past inflation for price and wage inflation respectively. However, as in Giannoni and Woodford (2005) the parameter φ that has been called the inverse of the pseudo-elasticity of intertemporal substitution will be estimated instead of σ. φ^-1 measures the sensitivity output to changes in the interest rate. The terms ξ_p, ξ_w, are all positive. Prices and wages are adjusted a la Calvo, where $1 - \alpha_p$ $(1 - \alpha_w)$ is the probability that the price (wage) is adjusted each period.[5] The parameter ξ_p represents the sensitivity of goods-price inflation to changes in the average gap between 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). $\omega_p > 0$ represents the elasticity of 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, equation (5), into the Phillips curve for wages, equation (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 $u_t^w = -w_t^n - w_{t-1}^n + \beta E_t w_{t+1}^n - \beta E_t w_t^n$.

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

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

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

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

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

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

3. Policymaker's Beliefs

Policymakers have imperfect information about the model of the economy and about the model's parameters. For that reason, policymakers approximate the true model of the economy by estimating a vector autoregressive (VAR) model. After estimating the value of the parameters in the VAR model every period, they implement optimal monetary policy summarized by i. The policymakers' beliefs about the state of the economy are characterized by their estimate of the parameters in the VAR. As in Primiceri (2006), policymakers estimate the coefficients of the model every period, and they expect that the parameters will remain the same in the future, leaving no room for experimentation.

3.1. The Policy Objective Function under Imperfect Information

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

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

Policymakers' preferences parameters are λ_p, λ_w, λ_x, and λ_i. As described earlier, the preferences parameters will be estimated assuming that there is a potential structural break in the third quarter of 1979. For that reason, two sets of preference parameters will be estimated, one that ends with the appointment of Paul Volcker to the Federal Reserve and the second regime starts right after.

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 wage and price inflation, the output gap and deviations of the nominal interest rate from its lagged value.[6]

Policymakers minimize their welfare loss function subject to the following constraints written in VAR form.

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

where $y_t = [x_t, \pi_t, W_t]'$ and i^f_t is the short term interest rate. The matrices μ, Γ, and T contain the coefficients $\hat{c}_y, \hat{c}_\pi, \hat{c}_w$, $\hat{b}1, \hat{c}1, \hat{d}1, \hat{b}2, \hat{c}2, \hat{d}2, \hat{b}3, \hat{c}3, \hat{d}3$, and $\hat{b}4, \hat{c}4, \hat{d}4$ that represent the policymakers' beliefs. Policymakers beliefs about the model's coefficients are represented by circumflexes.[7]

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

$$i_t = F(\hat{\phi}_t) z_t, \tag{11}$$

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:

$$i_t = F_x x_t + F_\pi \pi_t + F_w \pi^w_t + F_{il} i^f_{t-1}. \tag{12}$$

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

[6] 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). These and other reasons why interest rate smoothing is a desirable feature of the loss function are outlined in Dennis (2006).

[7] 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 in a model where the central bank perceives a costly trade off between inflation and the output gap in the 1970s.

of equations (1)-(5) along with the solution to the optimal policy problem expressed in structural form given by equation (12). In order to solve and estimate the model some assumptions are made in regards to the private sector's expectation formation process. As in Primiceri (2006) and Sargent (1999), the private sector knows policymakers' actions. In particular, private agents in the economy know policymakers' model given by equation (10) as well as 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 who will not revise their future estimates of the parameters in the model as in Kreps (1998). Agents think that policymakers will continue to implement policy based on their last estimate of equation (10).[8] Therefore, assuming that estimates $F(\hat{\phi}_t)$ in (11) will remain fixed into the future, equations (1)-(5) along with the solution to the optimal policy problem given by equation (12) are a linear rational expectations model.[9] 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 in order 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 of the shocks.

3.3. Learning

Policymakers estimate the parameters of the policymakers' model by Constant Gain Learning (CGL). CGL gives less value to past and more value to current observations. As addressed in Milani (2004), it represents a simple way to model learning when we know that there could be coefficient drifts, but we do not know when these drifts happen. The larger is the gain coefficient, the faster is learning of structural breaks. However, a larger coefficient also implies greater volatility around the steady state.

The VAR coefficients will be computed by updating previous estimates as additional data on output, inflation, wages, and lagged short term interest rates

[8]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 base of future data. However, Primiceri (2005) concludes that having fully rational agents is probably too strong and at odds with the data on the disinflation period

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

become available. Policymakers estimate their model using constant gain learning algorithms. The formulas used are specified below.

$$\widehat{\phi}_t^j = \widehat{\phi}_{t-1}^j + \mathbf{g} R_{j,t-1}^{-1} \chi_t (\zeta_t^j - \chi_t' \widehat{\phi}_{t-1}^j) \tag{13}$$

$$R_{j,t} = R_{j,t-1} + \mathbf{g}(\chi_t \chi_t' - R_{j,t-1}), \tag{14}$$

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, $\mathbf{g}$ is the gain coefficient and $\widehat{\phi}_t^{x_t} = [\widehat{c}_y, \widehat{b}1, \widehat{b}2, \widehat{b}3, \widehat{b}4]'$, $\widehat{\phi}_t^{\pi_t} = [\widehat{c}_\pi, \widehat{c}1, \widehat{c}2, \widehat{c}3, \widehat{c}4]'$, $\widehat{\phi}_t^{w_t} = [\widehat{c}_w, \widehat{d}1, \widehat{d}2, \widehat{d}3, \widehat{d}4]'$ collect the reduced form parameters. Equation (13) shows the updating rule for the central bank's beliefs, while equation (14) describes the updating formula for the precision matrix of the stacked regressors $R_{j,t}$. The updating formulas correspond to a weighted least squares estimator. As described in Milani (2010), policymakers revise their estimated coefficients in the direction of the most recent forecast errors. Lastly, the gain coefficient $\mathbf{g}$ governs the rate at which policymakers discount past information.

4. Bayesian Estimation Strategy

The model is estimated using Bayesian Techniques following An and Schorfheide (2007). I estimate both, the set of private sector model parameters and the policy preference parameters. The private sector model parameters include the structural and non-structural parameters, and corresponding standard deviations of the shocks, and the gain coefficient $\mathbf{g}$. I estimate the private sector parameters for the whole sample from 1960:II to 2008:I. However, to characterize the change in policymakers' preferences I estimate the policy parameters for two samples: the first sample runs from 1960:III to 1979:II, and the second sample runs from 1979:III to 2008:I. The second sample begins with Volcker's appointment as the Federal Reserve chairman. The superscript 1 denotes the first sample of estimated policy parameters, and the superscript 2 represents the second sample. I estimated the gain coefficient jointly $\mathbf{g}$ with the rest of the parameters in order to avoid obtaining results that are completely dependent on the central bank's learning process. The gain coefficient provides a link between the parameters estimated from the true model and the central bank's learning model in order to balance out the two possible explanations of the competing hypothesis. The initial beliefs correspond to OLS estimates of the policymakers' model using data from 1954:II to 1960:I. The estimation of the initial precision matrix for the learning rule would add too many degrees of freedom to the estimation and possibly favoring changes in beliefs over changes in preferences in this model.

The parameters are represented in a vector of 23 x 1 parameters denoted θ. The vector θ is composed by:

$$\theta = [\varphi, \eta, \xi_p, \omega_p, \omega_w, \gamma_p, \gamma_w, \lambda_x^1, \lambda_p^1, \lambda_w^1, \lambda_i^1, \lambda_x^2, \lambda_p^2, \lambda_w^2, \lambda_i^2, \tag{15}$$

$$\rho_r, \rho_p, \rho_w, \sigma_{mp}, \sigma_r, \sigma_p, \sigma_w, \mathbf{g}]'$$

The vector of observed variables consists of the output gap, the inflation rate, the deviation of 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 $Y^T = [Y_1, ..., Y_T]$. Lastly, 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 through a Metropolis Hastings algorithm.[10] The specific simulation method that I use is random walk Metropolis Hastings for which I ran 120,000 iterations, discarding the initial 20% as burn-in.

4.1. Data

The estimation was performed using quarterly data on output gap, inflation, real wage, and nominal interest rates. The data consists of two periods. The first period runs from 1960:I to 1979:II. The second period, which begins with Volcker's appointment as the Federal Reserve chairman, runs from 1979:III-2008:I. Inflation is measured by the annualized rate of change of the GDP implicit price deflator. The output gap for the private sector model is the log difference of the GDP and potential GDP estimated by the CBO. The real wage is measured by the log of the Non-farm business sector real compensation per hour from the BLS. Lastly, the nominal interest rate is represented by the federal funds rate.

[10]For details on the specification of the Metropolis Hastings algorithm refer to Chib and Greenberg (1995)

All data used were taken from the St. Louis Federal Reserve Economic Data website (FRED).

4.2. Priors

I estimated $\varphi \equiv [(1-\beta\eta)\sigma]^{-1}$. The prior for the parameter φ has a Gamma distribution with mean 1, and a standard deviation of 0.50 that is slightly lower than in Milani (2007a). The priors for habit persistence, price and wage inflation indexation, and price and wage inflation indexation in the loss function, follow a Beta distribution with mean of 0.50 and standard deviation of 0.22. This prior aids at estimating the 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' standard deviation . 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 (2007a). Furthermore, ω_p and ω_w follow a Gamma distribution with mean 0.89 and a large standard deviation; a Gamma distribution was assigned in this case because the model assumes that this parameters take a positive value.

The priors for the weights on the stabilization objectives of the policymakers' loss function are informative. They are centered at the values implied by the microfounded weights derived by Giannoni and Woodford (2005). The implied microfounded weights are functions of the underlying model parameters. The priors of the loss minimizing rates of wage and price inflation, dead weight loss, and interest smoothing parameter follow a gamma distribution. The loss minimizing rates of wage and price inflation, as well as the dead weight loss, are centered at 0.30, 1.00, and 0.30. These are means 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 of the interest rate smoothing parameter finds its mean at the value obtained by Dennis (2006). The standard deviations of the priors for wage and price inflation are 0.25 and 0.50, while the standard deviation for the dead weight loss and the interest rate smoothing prior take the values of 0.25 and 3.50.

5. Results

Table 2 presents the estimation results. The weights on price inflation on the policymakers' loss function for the period before the appointment of chairman Volcker to the Federal Reserve measured by λ_p^1 equals 1.165. After 1979, the estimate of the weight that policymakers give to price inflation λ_p^2 increased considerably to 3.563. The reported posterior probability intervals indicate that the estimates for the price inflation stabilization weights are different from one another in the pre and post-Volcker appointment eras. Therefore, there was a substantial change in preferences for inflation stabilization before and after the appointment of chairman Volcker to the Federal Reserve. This result is in line with the notion that interest rate policy in the Volcker-Greenspan period appears to have been much more sensitive to changes in inflation than in the pre-Volcker period as concluded in Clarida et al. (2000).

Policymakers' changed their preferences away from output gap stabilization from pre-Volcker's appointment to post-Volcker's appointment. Pre-Volcker the weight given to output stabilization (λ_x^1) was 1.397, this value decreased noticeably in the post-Volcker's appointment period to (λ_x^2) 0.340. This change in preferences coincides with the results reported in Dennis (2006). Dennis estimates the parameters in the Federal Reserve's policy objective function along with the parameters in the optimizing constraints. Dennis concludes that the estimated weight on the output gap in the objective function is not significantly different from zero in the post-Volcker era. He suggests that the Federal Reserve does 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. However, in the pre-Volcker era, the value estimated for the weight on the output gap is higher than in the post-Volcker period. The parameter values for dead weight loss in Dennis (2006) take values of 2.94 before 1979 and it increases to 3.14 after 1979. The weights that policymakers give to interest rate smoothing do not appear to be considerably different from the period before to after 1979 as perceived in the reported posterior probability intervals. The weight estimated for the interest rate smoothing parameter λ_i between the pre-Volcker period and the Volcker-Greenspan period take values of 0.326 and 0.335. Lastly, the weight that central bankers give to wage inflation stabilization decreases from the pre-Volcker period $\lambda_w^1 = 0.836$ to $\lambda_w^2 = 0.050$ in the Volcker

Greenspan period.

5.1. Policymakers' Beliefs and the Great Inflation

The Great Inflation that is the episode of high inflation that began in the late 1960s and ended in the early 1980s, can be explained in part by a change in beliefs about the state of the economy as in Primiceri (2006). Furthermore, there was a also a change in preferences reflected by changes in the weights given to output gap stabilization and inflation stabilization. The estimation suggests that there was an important change in the magnitude of the weight that central bankers in the U.S. give to inflation stabilization. Pre-1979 the weight that policymakers gave to inflation was much lower than post-1979. This implies that the beliefs of policymakers towards the persistence of inflation in the Phillips curve, and the beliefs toward the slope of the Phillips curve estimated in this paper support the "Overoptimistic" and "Overpessimistic" interpretation of the Great Inflation given by Primiceri (2006), and Romer and Romer (2002). In particular, The low value of the stabilizing weight on inflation estimated for the sample before 1979 supports the "Overoptimistic" and "Overpessimistic" interpretation of the Great Inflation

Figures 1 plots the real-time estimates of the AR(1) coefficient $\hat{c2}$ which represents a measure of perceived inflation persistence. During the early stages of the Great Inflation, policymakers in the model do not react strongly to inflation because they perceived a downward biased real time estimate of the persistence of inflation. Policymakers perceived that inflation would revert to its mean value at any time. Their estimates of the persistence of inflation were slowly revised upward.[11]

Figure 2 plots the real time estimates of the sensitivity of inflation to changes in the output gap $\hat{c1}$ of the perceived Phillips curve starting from 1960. During the later stages of the Great Inflation policymakers do not react strongly to the rise of inflation because they perceive a very unfavorable output gap – inflation trade off during the 1970s. Policymakers perceived that pushing output below its potential would only reduce inflation slightly. As discussed by De Long (1997) the cost of fighting inflation was not acceptable (during the 1970s), until the

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

perceived trade off between the output gap and inflation improved in the 1980s. Notice that *Figure 2* suggests that only *after* policymakers started to pursue policy devoted to bringing inflation down, the perceived cost of fighting inflation decreased. 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), where central bankers in the Inflation Stabilization era were willing to disinflate even if that translated into a "painful" unemployment episode. The results in this model conclude that entering into the Inflation Stabilization era the central bank focus shifted towards stabilizing inflation relative to the output gap. Therefore, monetary policy regime changes were, in fact, important to large movements in the trend of inflation in the U.S.

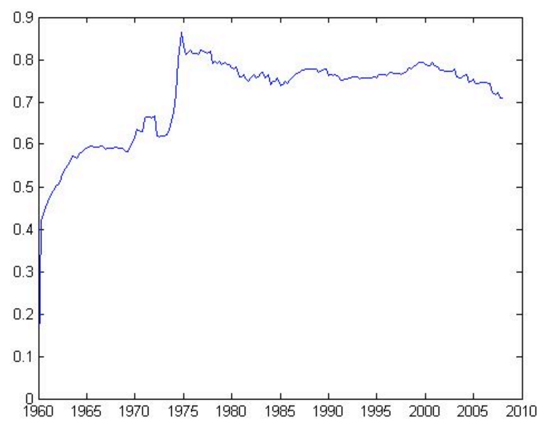

Figure 1: *Policymakers' Beliefs about the Persistence of Inflation in the Phillips Curve*

In order to grasp the monetary policy followed by policymakers in the model, *Figure 3* plots the evolution of the estimated model's optimal policy variable over time. In addition, the federal funds rate is plotted for comparison. As we can observe, the model's optimal policy variable follows closely the behavior of the federal funds rate in the period of study.

The contribution of this paper is to estimate the weights in the central bank loss function along with the structural parameters in a model that embeds policymakers' beliefs about the state of the economy. The estimates on the habit

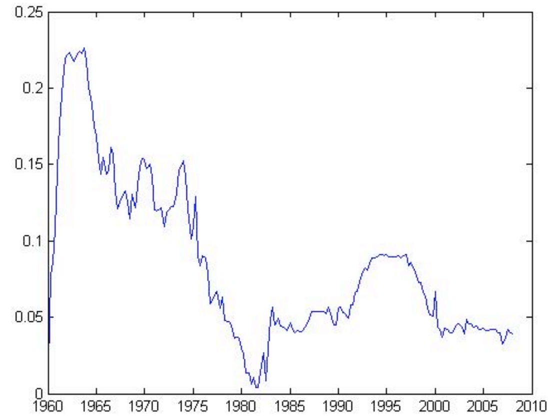

Figure 2: *Policymakers' Beliefs about the Slope of the Phillips Curve*

formation in consumption ($\eta = 0.030$), and ($\gamma_p = 0.032$) the degrees of indexation in price inflation are closely in line with the estimates in Milani (2007a). Substantial degrees of habit formation in consumption, and indexation in inflation are necessary to improve the fit of rational expectations models. However, when rational expectations are replaced by learning, mechanical sources of persistence are no longer needed to generate persistence in the economy as in Milani (2007a). In this model where the central bank is learning adaptively the degrees of habit formation and inflation indexation drop to lower values than what has been estimated for rational expectations models. The data is also informative in the estimation of the gain coefficient $\mathbf{g}$. The gain coefficient $\mathbf{g} = 0.016$ is consistent with previous estimations of this parameters in a similar setting as in Milani (2007a). This gain coefficient entails that the speed of learning of the central bank in this model is somewhat sluggish. The value estimated for the pseudo-intertemporal elasticity of substitution $\varphi = 6.045$, is higher than the value obtained in Giannoni and Woodford (2005) of 0.66 but in line with the value obtained in Milani (2007a). The rest of the parameters take similar values to previous Bayesian estimations of DSGE models for the U.S.

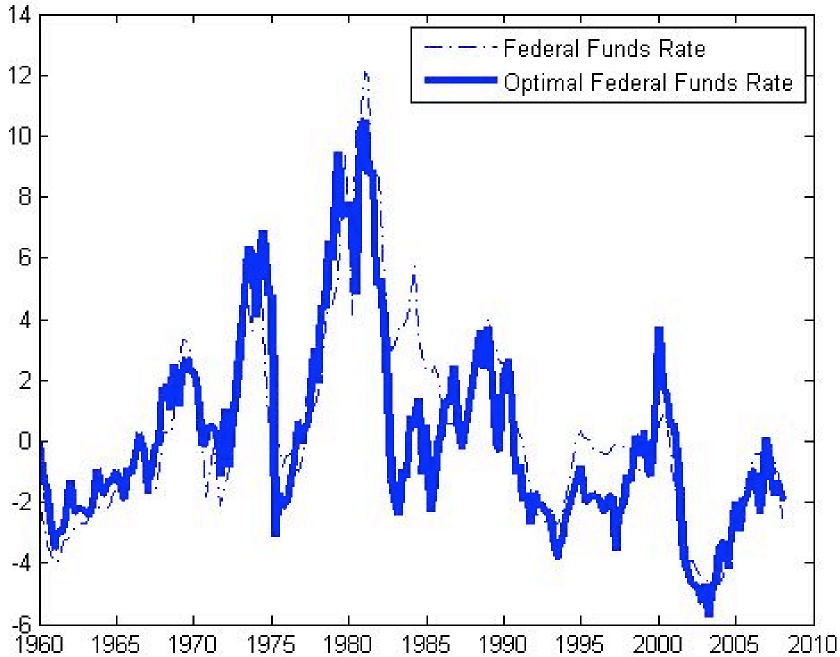

Figure 3: *Federal Funds Rate and Estimated Optimal Monetary Policy Variable*

5.2. Change in preferences, changes in policymakers' beliefs and their implied Taylor rule coefficients

In order to interpret the changes in the values of the stabilizing weights for inflation and output and the more stable weight estimated for interest rate smoothing this paper looks at their implied optimal interest rate responses. In particular, I present the response to inflation, the output gap, wage inflation, and interest rate smoothing, in the time-varying policy reaction function implied by the model given by equation (12). The results obtained from the time varying policy reaction function implied by the model can account remarkably for the Fed's time-varying responses to inflation (wage and price) in the period of study. This conclusion is reached after comparing the time-varying responses to the estimates in Ang et al. (2009). The authors 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 last 50 years. In a previous version of 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.

Figure 4 represents the time-varying responses to the output gap and inflation from 1960 to 2008. During most of the 70's policymakers had a preference for using the policy instrument to stabilize output gap as discussed earlier in the paper, but this changes after 1979. We can observe that during Volcker's disinflation, the response of the interest rate to the output gap decreases. Later on, the response of the interest rate to the output gap increases.

The time-varying coefficients on inflation (price and wage combined) implied by the estimated weights of the central bank loss function are very similar to the time-varying coefficient on inflation obtained in Ang et al. (2009). Ang et al. (2009) comments on the time varying coefficient that reflects the time-varying policy response to inflation. The authors find that the Fed's inflation coefficient starts to decrease during the 1960's. The coefficient stays low through the 1970s until 1979-1980. I obtain a similar easing of monetary policy pattern in the time-varying coefficient on inflation (price and wage combined) during the 1960s and 1970s. In Ang et al. (2009) the Fed's inflation response starts to increase in the late 1979. As in Boivin (2006) they do not observe that the most pronounced increase in inflation response in the late 1979 (with the appointment of Volcker to the Fed) as is often assumed. The highest response to inflation was reached in 1984. In this paper also the Fed's response to inflation starts rising in the early 1980s. The response to wage inflation reaches a high response some time in the mid 1980s. Furthermore, Ang et al. (2009) obtain a response to inflation that starts to decrease in the 1980s, subsequently the response starts to increase some time close to the mid 1990s and stays high during most of the decade. The parameters in this paper follow a similar pattern. The 2001 recession is accompanied by a low response to inflation in this paper and in Ang et al. (2009) followed by an increased response to inflation by the Fed in 2003. Lastly, the low response to inflation during the current financial and economic crisis is consistent with the estimates obtained in Ang et al. (2009).

The time-varying interest rate smoothing parameter is depicted in *Figure 5* . The interest smoothing time varying parameter increases gradually during the whole period. However the stabilizing weight for interest rate smoothing in the policy objective function does not change from before to after 1979.

The paper's empirical results show that the implied time-varying Taylor rule coefficients depend, in fact, not only on the weights, but also on the policymakers' beliefs of the structure of the economy. In an attempt to understand the contribution of the change in policymakers' preferences compared to the changes in beliefs, two counterfactual experiments were conducted. The counterfactual experiments are plotted in *Figures 6, 7. Figure 6* reports the time-varying Taylor rule coefficients when the weights in the central bank's objective function are held constant over the whole period at the first sample's estimates in a model where the central bank is learning.

Figures 6.b and *6.c* show the time-varying Taylor rule response to inflation (wage and price). In both figures, the average time varying response to inflation after 1979 is too low compared to the benchmark model. Therefore, changing policymakers' beliefs by themselves and fixing the policymakers' preferences to pre-1979 values cannot fully account for the shifts in the policy dynamics of the inflation responses in the benchmark model.

Figure 7 represents the case where the preference parameters are fixed to their post 1979 levels during the whole sample, with policymakers' learning. *Figures 7.b* and *7.c* show the time varying coefficient on inflation (price and wage). In this case I find a strong response to inflation during the 1960s and 1970s, which is not consistent with the policy dynamics present in the benchmark model or with previous estimates of the time varying response to inflation.

5.2. Robustness

This section examines the robustness of results to a different assumption in regard to 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) in which the output gap, inflation, and detrended wages are responding to two lags of the output gap, inflation, and detrended wages, as well as two lags of the short term interest rate. Primiceri (2006) and Pruitt (2010) estimate models that include two lags in their central bank models. All conclusions are robust to having a model of the central bank in which a different number of lags is considered. I find that there was a change in preference for inflation stabilization from the period before to after 1979. The weight on price inflation increased from $\lambda_p^1 = 0.0158$ to $\lambda_p^2 = 2.471$ after 1979. In addition, I find that policymakers perceived an unfavorable output gap - inflation

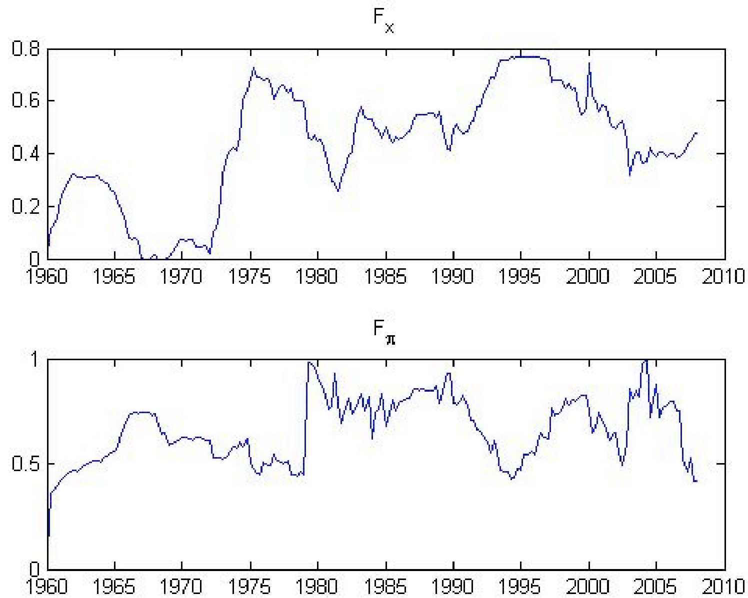

Figure 4: *(a) Output Gap and (b) Inflation Responses in the Model's Time-Varying Policy Reaction Function*

trade off, [12] as measured by the sensitivity of inflation to the output gap in the inflation equation. This perceived inflation-output gap trade off coincides with the dynamics observed in Carboni and Ellison (2009). The perceived cost of fighting inflation did not improve until the 1980s after policymakers started to pursue disinflationary policy. This was after the shift in preference for inflation stabilization took place.

6. Conclusions

The rise and subsequent fall of inflation in the United States during the 1970s and 1980s –the "Great Inflation"– has been subject of extensive research. One approach holds that monetary policymakers during the late 1960s and throughout the 1970s preferred stabilizing output, while post 1979 they preferred inflation stabilization. An alternative explanation contends that the Federal Reserve held misperceptions about the state of the economy and the transition equations for the economy. This paper studies the Great Inflation in a medium scale macroe-

[12] *Figure 10*plots of the sensitivity of inflation to the output gap in a VAR(2) model of the central bank.

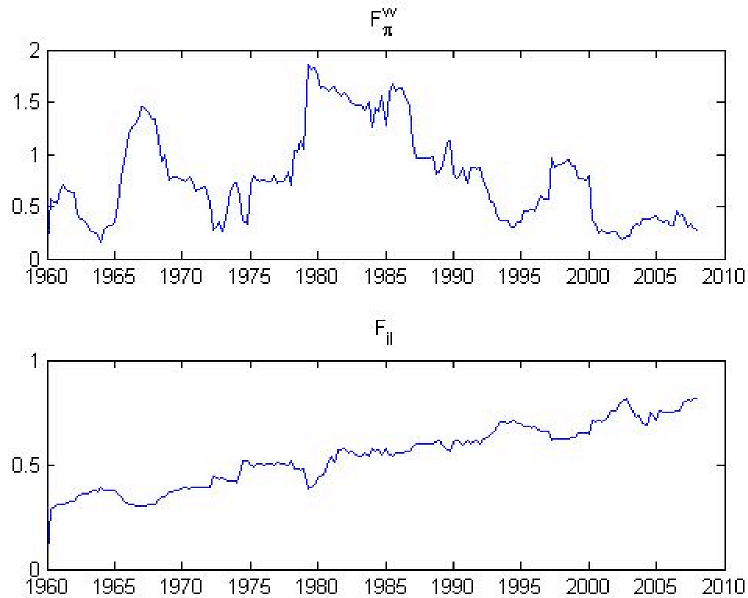

Figure 5: *(a) Wage Inflation and (b) Lagged Interest Rate Responses in the Model's Time-Varying Policy Reaction Function*

conomic model that embeds both a possible change in policymakers' preferences from the Great Inflation into the inflation stabilization era and changing beliefs, through learning, about the state of the economy. By combining both elements, the learning hypothesis with the policymakers' shift in preferences, the empirical results illustrate the extent to which changes in the *perceived* inflation – output trade off or the *preferred* inflation – output trade off explain the Great Inflation.

This paper provides evidence of a change in the estimated weights that central bankers give to output gap stabilization, and inflation stabilization after 1979, even in the presence of a model where policymakers are learning about the state of the economy over time. However, there is not much evidence that the weight estimated for interest rate smoothing change from pre-Volcker to post-Volcker's appointment. The weight that central bankers in this model put on stabilizing the output gap approaches zero in the post-Volcker's appointment period. This shows that policymakers in the 1970s bore in mind the Great Depression and did not make policy decisions that would translate into a sizable 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.

Policymakers changed their preference for inflation stabilization as well. The inflation stabilization weight increased in the Volcker-Greenspan period. This result is in line with the notion that interest rate policy in the Volcker-Greenspan period had been more sensitive to changes in inflation than in the pre-Volcker period. But more importantly, the responses of the output gap and inflation (wage and price) in the time-varying policy reaction function implied by the model are very similar to previous estimates of time-varying Taylor rule coefficients. This paper concludes that although there were changes in the estimated stabilizing weights on price inflation and the output gap, there were no significant changes in the stabilizing weights estimated for interest rate smoothing. Therefore, *both* policymakers' learning and changes in preferences, aid in representing the Fed's time-varying policy response to inflation, and to explaining the dynamics present in the Fed's policy instrument.

7. Appendix

7.1. Appendix I. on Model Derivation (Provided for the Reader's Benefit)

The following optimizing model is a DSGE model in the spirit of Erceg et al. (2000), Woodford (2003), Giannoni and Woodford (2005). This model includes internal habit persistence, wage stickiness, and inflation inertia, which have proven to improve the empirical properties of the model, giving more realism to the transmission mechanisms.

The structural equations that give the aggregate dynamics of output, price, and wage inflation are described in the following section.

7.1. Optimal consumption decisions

The economy is composed by a continuum of households h distributed uniformly on the [0,1] interval. Each household supplies a differentiated labor service to the production sector. Thus, firms regard each household's labor as an imperfect substitute of the other household's labor. A labor aggregator bundles the household's labor hours in the same proportions as firms would choose. Each household h maximizes a lifetime expected utility that can be written as follows.

$$E_t \sum_{T=t}^{\infty} \beta^{T-t}[u(C_T^h - \eta C_{T-1}^h; \zeta_T) - v(H_T^h; \zeta_T)], \tag{16}$$

where β is the household's discount factor, C_T^h is a Dixit-Stiglitz index of household's consumption of each of the differentiated goods supplied at time t, and H_t^h is the amount of labor (type h) supplied by the household h at time t. The parameter $0 \leq \eta \leq 1$ represents the degree of habit formation. Each household obtains utility from the excess consumption at date t relative to some habit stock ηC_{t-1}. ζ_T is a vector of exogenous preference shocks. The function $u(\cdot; \zeta_T)$ is increasing and concave for each value of ζ_T, while $v(\cdot; \zeta_T)$ is increasing and convex. This model assumes that capital is fixed and cannot be instantaneously relocated among firms in order to equalize the return to capital services across firms that change their prices at different prices.The CES Dixit-Stiglitz consumption index is given by:

$$C_t^h \equiv \left[\int_0^1 c_t^h(j)^{\frac{\theta_p - 1}{\theta_p}} dj\right]^{\frac{\theta_p}{\theta_p - 1}} \tag{17}$$

and the price index is:

$$P_t \equiv \left[\int_0^1 p_t(j)^{1-\theta_p} dj\right]^{\frac{1}{\theta_p - 1}}, \tag{18}$$

where $c_t^h(j)$ aggregates consumption of each good (j) and $\theta_p > 1$ stands for the elasticity of substitution between differentiated goods. Optimal consumption of good j is given by $c_t^h(j) = C_t^h(p_t(j)/P_t)^{-\theta_p}$, where $p_t(j)$ is the price of good j at date t.

In this model, financial markets are complete so that risks are efficiently shared. As a result, each household faces a single intertemporal budget constraint given by:

$$P_t C_t^h + E_t[Q_{t,t+1} A_{t+1}^h] \leq A_t^h + w_t(h) H_t^h + \Pi_t(h) - T_t, \tag{19}$$

where A_t^h is the nominal value of the household's beginning-of-period financial wealth, $w_t(h)$ denotes nominal wage of labor h, $\Pi_t(h)$ stands for the profits from sales of good h, and T_t represents the nominal value of (net) lump-sum taxes. $Q_{t,T}$ is the stochastic discount factor that defines the market valuations of alternative random income streams. The riskless one-period nominal interest rate, i_t, must satisfy

$$(1+i_t)^{-1} = E_t Q_{t,t+1}. \tag{20}$$

The first order conditions for the optimal choice of consumption is given by

$$\Lambda_t P_t = u_c(C_T - \eta C_{T-1}; \zeta_T) - \beta\eta u_c(C_{T+1} - \eta C_t; \zeta_{T+1}). \tag{21}$$

Λ_t that denotes the representative household's marginal utility of real income at time t.[13]

The marginal utilities of income at different dates and states must satisfy

$$\Lambda_t Q_{t,T} = \beta^{T-t}\Lambda_T, \tag{22}$$

for any possible state at any date $T \geq t$. Equations (22) and (20) results in the Euler equation for optimal timing of consumption. The Euler equation links the interest rate to the evolution of the marginal utility of income in the following equilibrium relationship:

$$\Lambda_t P_t = \beta E_t[(1+i_t)\frac{P_t}{P_{t+1}}\Lambda_{t+1}P_{t+1}]. \tag{23}$$

Log-linear approximations of these relationships were performed around steady state equilibrium with no inflation. Log-linearizing equation (23) yields

$$\hat{\lambda}_t = E_t[\hat{\lambda}_{t+1} + \hat{i} - \pi_{t+1}], \tag{24}$$

where $\hat{\lambda}_t \equiv \log \frac{\Lambda_t P_t}{\bar{\lambda}}, \hat{i}_t \equiv \log\ (\frac{1+i_t}{1+\bar{i}})$, and $\pi_t \equiv \log(\frac{P_t}{P_{t-1}})$ Using equation (29) and log-linearizing equation (21) yields:

$$\widetilde{C}_t = E_t\widetilde{C}_{t+1} - (1-\beta\eta)\sigma(\hat{i}_t - E_t\hat{\pi}_{t+1}) + g_t - E_t g_{t+1}, \tag{25}$$

[13] As in Giannoni and Woodford (2005) the problem is the same for each household since the initial level of wealth is assumed to differ among households in a way that it compensates for any differences in their expected labor incomes. All households choose identical state-contingent plans of consumption, thus, I drop the index "h''" in the consumption variable.

where

$$\widetilde{C}_t \equiv (\hat{C}_t - \eta\hat{C}_{t-1}) - \beta\eta E_t(\hat{C}_{t+1} - \eta\hat{C}_t) \tag{26}$$

σ is the intertemporal elasticity of substitution of consumption in the absence of habit formation, exogenous preference shocks are represented by g_t, and $\hat{C}_t$, $\hat{i}_t$,and$\hat{\pi}_t$ represent log-deviations of consumption, nominal interest rates, and inflation from their steady-state values.[14] Aggregate demand is $Y_t = C_t$. Rewriting (26) in terms of the output gap $x_t \equiv Y_t - Y_t^n$ where Y_t^n indicates log deviations from in the natural rate of output, [15] I obtain the intertemporal IS relation:

$$\widetilde{x}_t = E_t\widetilde{x}_{t+1} - (1-\beta\eta)\sigma[i_t - E_t\pi_{t+1} - r_t^n], \tag{27}$$

where

$$\widetilde{x}_t \equiv (x_t - \eta x_{t-1}) - \beta\eta E_t(x_{t+1} - \eta x_t) \tag{28}$$

and $r_T^n \equiv [(1-\eta\beta)\sigma]^{-1}[(Y_{t+1}^n - g_{t+1}) - (Y_t^n - g_t)]$ is the flexible price real interest rate that represents the real interest rate when $x_t = 0$ at all times where g_t represents exogenous preference shocks.

7.2. Equilibrium Wage Setting

Following Erceg et al. (2000), Amato and Laubach (2003), Woodford (2003), and Giannoni and Woodford (2005) I assume that there is a single labor market in the economy. Firm j is a monopolistic supplier of good j, which has the following production function

$$y_t(j) = A_t F(\overline{K}, H_t(j)) \equiv A_t f(H_t(j)), \tag{29}$$

where A_t is an exogenous technology factor, the function f is increasing and concave, and capital is fixed so that labor is the only variable input. The labor index $H_t(j)$ used to produce each good j has the Dixit-Stiglitz form:

[14] The ˆ designation will be omitted in the rest of the paper for conciseness.

[15] The natural rate of output means the equilibrium level of output under flexible prices, flexible wages, and constant levels of distorting taxes and of desired markups in the labor and product markets.

$$H_t(j) \equiv \left[\int_0^1 H_t^h(j)^{\frac{\theta_w - 1}{\theta_w}} dh] \right]^{\frac{\theta_w}{\theta_w - 1}} \tag{30}$$

for some elasticity of substitution $\theta_w > 1$ where $H_t^h(j)$ is the labor of type h that is hired to produce a given good j. The demand for labor type h by firm j is obtained by the maximizing of index (30) for a given level of wage payments. It is characterized by $H_t^h(j) = H_t(j) \left(\frac{w_t(h)}{W_t} \right)^{-\theta_w}$, where $w_t(h)$ is the nominal wage of labor of type h, and W_t is a wage index

$$W_t \equiv \left[\int_0^1 w_t(h)^{1-\theta_w} dh] \right]^{\frac{1}{1-\theta_w}}. \tag{31}$$

The monopolistic supplier of each type of labor sets the wage for each type of labor. Each monopolistic supplier is ready to supply as many hours of work to be demanded at that wage. Integrating across firms, the demand for labor faced by households h is $H_t^h(j) = H_t \left(\frac{w_t(h)}{W_t} \right)^{-\theta_w}$ where $H_t \equiv \int_0^1 H_t(z)dz$. Each monopolistically competitive worker of type h , sets wage $w_t(h)$ assuming that it has a negligible impact on the wage index W_t. In addition, analogous to the Calvo model of staggered pricing, each wage is unchanged with a fixed probability $1-\alpha_w$ each period. As in Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003), Altig et al. (2004), and Woodford (2003, ch. 3) if a wage is not reoptimized, it is adjusted according to the indexation rule $\log w_t(h) = \log w_{t-1}(h) + \gamma_w \pi_{t-1}$ for some $0 \leq \gamma_w \leq 1$ that represents the degree of indexation to past inflation.

A worker of type h who chooses a new wage $w_t(h)$ at date t, expects to have a wage $w_t(h)(P_{T-1}/P_{t-1})^{\gamma}$ with probability α_w^{T-t} at any time $T \geq t$. Giving this wage profile the worker will face a demand of

$$H_T(\frac{w_t(h)\frac{P_{T-1}}{Pt-1}^{\gamma_w}}{W_T}))^{-\theta_w} \tag{32}$$

for his work. Newly optimized wages, which take effect immediately w_t^*, are chosen at the end of period t-1, with information available at t-1. A new wage w_t^* adjusted in period t should be selected to maximize

$$E_t \sum_{T=t}^{\infty} (\alpha_w \beta)^{T-t} [\Lambda_T (1+\tau_w) w_t(h) \left(\frac{P_{T-1}}{P_{t-1}} \right)^{\gamma} H_T \left(\frac{w_t(h) \left(\frac{P_{T-1}}{P_{t-1}} \right)^{\gamma_w}}{W_T} \right)^{-\theta_w} \tag{33}$$

$$-v \left(H_T \left(\frac{w_t(h) \left(\frac{P_{T-1}}{P_{t-1}} \right)^{\gamma}}{W_T} \right)^{-\theta_w} ; \xi_T \right)].$$

$0 \leq \tau < 1$ is a subsidy for employment that offsets the effect on imperfect competition in labor markets on the steady- state level of output. Λ_T is the representative household's marginal utility of nominal income at date T. The solution to this problem satisfies the first order condition

$$0 = E_t \{ \sum_{T=t} \imath nfty (\alpha_w \beta)^{T-t} \left[H_T (w_t^*)^{-\theta_w - 1} \left(\frac{P_{T-1}/P_{t-1}{}^{\gamma w}}{W_T} \right)^{-\theta_w} (1-\theta_w) \right] \tag{34}$$

$$\left[\Lambda_T w_t^* \left(\frac{P_{T-1}}{P_{t-1}} \right)_w^{\gamma} - \mu_w v_h \left(H_T \left(\frac{w_t^* (P_{T-1}/P_{t-1})^{\gamma w}}{W_T} \right)^{-\theta_w} ; \xi_T \right) \right] \},$$

where v_t is the geometric average of the marginal rate of substitution (MRS) between work and consumption for the supplier of a given type of labor, and $\mu_w = \theta_w / (\theta_w - 1) > 1$ is the desired markup of household's real-wage demand over its marginal rate of substitution owing to its monopoly power. The optimal wage w_t^* is equal across all h, since the function $v(H, \xi)$ is the same across all h, and the optimization problem solved by the each household is the same. The optimal wage w_t^* is determined implicitly by the previous equation. Given the choice of w_t^* each period, the overall wage index evolves according to

$$W_t = \left[(1-\alpha_w) w_t^{*1-\theta_w} + \alpha \left(W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} \right)^{1-\theta_w} \right]^{\frac{1}{1-\theta_w}} . \tag{35}$$

The log-linearization will be performed under the assumption that W_t/P_t, P_t/P_{t-1}, and w_t^*/W_t will remain close to their steady state values , $\overline{w}$, 1, and 1 respectively. Log-linearizing equation (35) results in

$$\hat{w}_t^* = \frac{\alpha_w}{1-\alpha_w} (\pi_t^w - \gamma_w \pi_{t-1}), \tag{36}$$

where $\hat{w}_t^* \equiv$log(w_t^*/W_t), $\pi_t^w \equiv \log(W_t/W_t - 1)$. A log-linear approximation to the first-order condition yields

$$0 = E_t \left\{ \sum_{T=t}^{\infty} (\alpha_w \beta)^{T-t} \left[(1 + \nu\theta_w)) \left(\hat{w}_t^* - \sum_{\tau=t+1}^{\infty} (\pi_\tau^w - \gamma_w \pi_{\tau-1} \right) + \hat{\omega}_T - \hat{v}_T \right] \right\}, \tag{37}$$

where $\nu \equiv \frac{v_h h \overline{H}}{v_h}$, $\hat{H} \equiv \log H_t/\overline{H}$and $\hat{\omega}_t \equiv log\left(\frac{W_t/P_t}{\overline{\omega}}\right)$ is the percent deviation of the real wage from steady-state, and

$$\hat{v}_t \equiv \nu \hat{H}_t + \frac{v_h \xi}{v_h} \xi_t - \hat{\lambda}_t \tag{38}$$

is the geometric average of the deviation from steady state of the MRS between work and consumption. Solving the log-linearized first-order for $\hat{w}_t^*$ yields

$$\hat{w}_t^* = E_t \left\{ \left[\sum_{T=t}^{\infty} (\alpha_w \beta)^{T-t} \left[(\pi_T^w - \gamma_w \pi_{T-1}) + \frac{1 - \alpha_w \beta}{1 + \upsilon \theta_w} (\hat{\omega}_T - \hat{v}_T) \right] \right] - (\pi_t^w - \gamma_w \pi_{t-1}) \right\}. \tag{39}$$

Quasi-differencing this equation and making use of equation (36) results in

$$\pi_t^w - \gamma_w \pi_{t-1} = \xi_w (\hat{v}_t - \hat{\omega}_t) + \beta E_t (\pi_{t+1}^w - \gamma_w \pi_t) + u_t^w, \tag{40}$$

where $\xi_w \equiv \frac{(1-\alpha_w)(1-\alpha_w\beta)}{\alpha_w(1+\nu\theta_w)>0}$. The production function was log-linearized, and taking into consideration that the steady-state value of A_t is 1 results in

$$\hat{y}_t(j) = a_t + \phi^{-1} \hat{H}_t(j),$$

where $\hat{y}_t(j) \equiv \log(y_t(j)/\overline{Y})$, $a_t \equiv$log(A_t), $\hat{H}_t \equiv$log$(H_t(j)/\overline{H})$, and $\phi \equiv \frac{f(\overline{H})}{\overline{H} f'(\overline{H})} > 1$. Solving for $\hat{H}_t$ yields

$$\hat{H}_t = \phi(\hat{Y}_t - a_t).$$

Substituting this into equation (38) the following is obtained

$$\hat{v}_t = \omega_w (Y_t - a_t) + \frac{v_h \xi}{v_h} \xi_t - \hat{\lambda}_t. \tag{41}$$

The parameter $\omega_w \equiv \upsilon\phi > 0$ indicates the degree to which higher economic activity increases workers' desired wages for given prices. The expression of the natural rate of output is given by

$$\omega_w \hat{Y}_t^n = (1+\omega)a_t - \frac{\upsilon_h \xi}{\upsilon_h}\xi_t + \hat{\lambda}_t^n. \tag{42}$$

Taking into consideration the previous equation, the marginal rate of substitution between labor and consumption can be expressed as

$$\hat{\upsilon}_t = \omega_w x_t + [((1-\beta\eta)\sigma)^{-1}\widetilde{x} + \hat{w}_t^n], \tag{43}$$

where

$$\hat{w}_t^n \equiv (1+\omega_p)a_t - \omega_p \hat{Y}_t^n \tag{44}$$

represents percent deviation from the steady state natural real wage. Lastly, the wage-inflation equation (40) can be written as an aggregate-supply relation of the form

$$\pi_t^w - \gamma_w \pi_{t-1} = \xi_w[\omega_w x_t + [(1-\eta\beta)\sigma]^{-1}\widetilde{x}_t] + \xi_\omega(w_t^n - w_t) + \beta E_t(\pi_{t+1}^w - \gamma_w \pi_t) + u_t^w, \tag{45}$$

where $\xi_w = \frac{(1-\alpha_w)(1-\alpha_w\beta)}{\alpha_w(1+\upsilon\theta_w)}$ is a function of the degree of wage stickiness, the elasticity of marginal disutility of labor supply at the steady state, $\upsilon \equiv \frac{\upsilon_{hh}\overline{H}}{\upsilon_h}$ and the elasticity of substitution for different types of labor.

7.3. Equilibrium Price Setting

Similarly, the suppliers of goods are monopolistically competitive and each price is chosen optimally with probability $1-\alpha_p$ in a given period. As in Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003), Altig et al. (2004), Giannoni and Woodford (2005), and Woodford (2003, ch. 3) if a price is not reoptimized, it is adjusted according to the indexation rule

$$\log p_t(j) = \log p_{t-1}(j) + \gamma_p \pi_{t-1}. \tag{46}$$

Every firm solves the same decision problem, and when they change their price, they set a common price at p_t^*. The aggregate price evolves according to

$$P_t = \left[\alpha_p \left(P_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_p}\right)^{1-\theta_p} + (1-\alpha_p) p_t^{*1-\theta_p}\right]^{\frac{1}{1-\theta_p}} \tag{47}$$

for some $0 \leq \gamma_p \leq 1$. Log-linearizing equation (47) results in

$$\hat{p}_t^* = \frac{\alpha_p}{1-\alpha_p}(\pi_t - \gamma_p \pi_{t-1}). \tag{48}$$

Each firm selects its new price p_t^* in order to maximize the expected present discounted value of future profits

$$E_t\left\{\sum_{T=t}^{\infty} \alpha_p^{T-t} Q_{t,T}[\Pi_T(p_t)]\right\}, \tag{49}$$

where $Q_{t,T}$ is the stochastic discount factor that defines the market valuations of alternative random income streams. Nominal profits Π_T are given by

$$\Pi_T(p) = p\left(\frac{P_{T-1}}{P_{t-1}}\right)^{\gamma_p}\left(\frac{p(P_{T-1}/P_{t-1})^{\gamma_p}}{P_T}\right)^{-\theta_p} Y_t - W_t f^{-1}\left(\left(\frac{p(P_{T-1}/P_{t-1})^{\gamma_p}}{P_T}\right)^{-\theta_p}\frac{Y_T}{A_T}\right). \tag{50}$$

The solution to this problem satisfies the first order condition

$$0 = E_t\{\sum_{T=t}^{\infty}(\alpha_p\beta)^{T-t}\left[\frac{\Lambda_T}{\Lambda_t}(p_t^*)^{-\theta_p-1}\left(\frac{(P_{T-1}/P_{t-1})^{\gamma_p}}{P_T}\right)^{-\theta_p}(1-\theta_p)P_T Y_T\right] \tag{51}$$

$$\left[\frac{p_t^*}{P_T}\left(\frac{P_{T-1}}{P_{t-1}}\right)^{\gamma_p} - \mu_p \frac{W_T/P_T}{A_T f'\left(f^{-1}\left(\left(\frac{p_t^*(P_{T-1}/P_{t-1})^{\gamma_p}}{P_T}\right)^{-\theta_p}\frac{Y_T}{A_T}\right)\right)}\right]\},$$

where $\mu_w = \theta_w/(\theta_w - 1) > 1$. The optimization problem is the same for all firms, therefore the optimal price p_t^* is the same for all firms. Log-linearizing the previous equation around a steady state results in

$$0 = E_t\left\{\sum_{T=t}^{\infty}(\alpha_p\beta)^{T-t}\left[(1+\omega_p\theta_p)\left(\hat{p}_t^* - \sum_{\tau=t+1}^{T}(\pi_t - \gamma_p\pi_{t-1})\right) - \hat{\omega}_T - \hat{\psi}_T\right]\right\}, \tag{52}$$

ω_p indicates the degree to which higher economic activity increases producers' desired prices given wages, $\hat{p}_t^* \equiv \log(\hat{p}_t^*/P_t), \hat{\omega}_t \equiv \log(\frac{W_t/P_t}{\overline{w}})$ and

$$\hat{\psi}_t \equiv \omega_p \hat{Y}_t - (1+\omega_p)a_t \tag{53}$$

$\hat{\psi}_t$ represents minus the average deviation across firms of log of the marginal product of labor from its steady state. Solving the log-linearized first-order condition equation (52) yields

$$\hat{p}_t^* = E_t \left\{ \left[\sum_{T=t}^{\infty} (\alpha_w \beta)^{T-t} \left[(\pi_T - \gamma_p \pi_{T-1}) + \frac{1-\alpha_p\beta}{1+\omega_p\theta_p}(\hat{\omega}_T - \hat{\psi}_T) \right] \right] - (\pi_t - \gamma_p \pi_{t-1}) \right\}. \tag{54}$$

Quasi differencing this equation and making use of equation (48) gives

$$\pi_t - \gamma_p \pi_{t-1} = \xi_p(\hat{\omega}_T + \hat{\psi}_T) + \beta E_t(\pi_{t+1} - \gamma_p \pi_t) + u_t^p. \tag{55}$$

Writing the previous equation in terms of deviations from steady state output and the natural rate of output gives

$$\pi_t - \gamma_p \pi_{t-1} = \kappa_p(\hat{Y}_t - \hat{Y}_t^n) + \xi_p(\hat{w}_t - \hat{w}_t^n) + \beta E_t(\pi_{t+1} - \gamma_p \pi_t) + u_t^p \tag{56}$$

$$\hat{w}_t^n \equiv (1+\omega_p)a_t - \omega_p \hat{Y}_t^n, \tag{57}$$

where $\hat{w}_t^n$ represents the percent deviation from steady state value of the natural real wage and w_t^n is defined as the log of the natural real wage and w_t is the log real wage. Therefore, equation (53) can be further expressed as relation of the form

$$\pi_t - \gamma_p \pi_{t-1} = \kappa_p x_t + \xi_p(w_t - w_t^n) + \beta E_t(\pi_{t+1} - \gamma_p \pi_t) + u_t^p, \tag{58}$$

where $\kappa_p = \xi_p \omega_p$, $\xi_p = \frac{(1-\alpha_p)(1-\alpha_p\beta)}{\alpha_p(1+\omega p \theta_p)}$ is a function of the degree of price stickiness.

7.2. Appendix II. State Space Form and Optimal Policy

The optimization constraints have the following state space representation.

$$z_{t+1} = C_t + A_t z_t + B_t i_t + e_{t+1} \tag{59}$$

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 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:

$$E_t \left\{ \sum_{j=0}^{\infty} \beta^j [(z_{t+j})' Q (z_{t+j}) + (i_{t+j})' R (i_{t+j}) + 2(z_{t+j})' U (i_{t+j})] \right\} \tag{60}$$

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

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

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

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

$$i_t = F(\hat{\phi}_t) z_t, \tag{61}$$

where

$$F = -(R + \beta BPB)^{-1}(V + \beta B'PA) \tag{62}$$

$$P = Q + \beta A'PA - (\beta A'PB + U')(R + \beta B'PB)^{-1}(\beta B'PA + U). \tag{63}$$

Equation (63) is a matrix Riccati equation. In order 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:

$$i_t = F_x x_t + F_\pi \pi_t + F_w \pi_t^w + F_{il} i_{t-1}^f. \tag{64}$$

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

7.3. Appendix 3. Model Overview

It is useful to provide a brief overview of the economic model. Policymakers utilize the time series data on the variables in the economy in order 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 in order to formulate a policy rule for i_t. The private sector takes that policy rule and forms rational expectations. Lastly, the preference parameters, gain coefficient and the structural coefficients of the true model are jointly estimated using Bayesian methods.

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] Amato, Jeffery, and Thomas Laubach. (2003). "Estimation and control of an optimizing-based model with sticky prices and wages." *Journal of Economic Dynamics and Control* 27(7), 1181-1215.

[3] An, Sungbae, and Frank Schorfheide. (2007). "Bayesian Analysis of DSGE Models." Econometric Reviews 26 (2-4), 113-172.

[4] Ang, Andrew, Jean Boivin, Sen Dong, and Rudy Loo-Kung. (2009). "Monetary Policy Shifts and the Term Structure 2009." Forthcoming *Review of Economic Studies*.

[5] Boivin, Jean, and Marc Giannoni. (2006). "Has monetary policy become more effective?" *Review of Economics and Statistics*, 88 (3), 445-462.

[6] Branch, William. A., and George W. Evans. (2006). "A Simple Recursive Forecasting Model." *Economic Letters* 91 (2), 158-166.

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

[8] Bullard, James, and Kaushik Mitra. (2002). "Learning About Monetary Policy rules." *Journal of Monetary Economics*, 49, 1105-1129.

[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] Christiano, Larry, Martin S. Eichenbaum, and Charles Evans. (1999). "Monetary Policy Shocks: What Have We Learned and to What End?" *Handbook of Macroeconomics,* 1A.

[12] 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.

[13] Clarida, Richard, Jordi Galí, and Mark Gertler. (2005). "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37, 1661-1707.

[14] Clarida, Richard, Jordi Galí, and Mark Gertler. (2000). "Monetary Policy rules and Macroeconomic Stability: Evidence and Some Theory." *The Quarterly Journal of Economics* 37, 147-180.

[15] 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.

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

[17] De Long, Brad. (1997). "America's Only Peacetime Inflation: The 1970s." In Romer C., Romer D. (Eds.), Reducing Inflation. University of Chicago Press, Chicago, IL.

[18] Del Negro, Marco, and Frank Schorfheide. (2008). "Forming Priors for DSGE Models (and How it Affects the Assessment of Nominal Rigidities,)." *Journal of Monetary Economics* 55(7), 1191-1208.

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

[20] 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.

[21] Evans, George, and Seppo Honkapohja. (2001). *Learning and Expectations in Macroeconomics Monetary.* Princeton University Press, Princeton, New Jersey.

[22] Evans, George, and Seppo Honkapohja. (2003). "Adaptive Learning and Monetary Policy Design." *Journal of Money, Credit and Banking* 35(6), 1045-1073.

[23] Giannoni Marc, and Michael Woodford., (2005). "Optimal Inflation-Targeting Rules." In: Bernanke B.S., Woodford, M. (Eds.), Inflation Targeting, University of Chicago Press.

[24] 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.

[25] Lubik, Thomas and Frank Schorfheide. (2004). “Testing for Indeterminacy: An Application to U.S. Monetary Policy.” *American Economic Review* 94(1),190-219.

[26] Milani, Fabio. (2004). “Adaptive learning and inflation persistence.” mimeo. Princeton University.

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

[28] Milani, Fabio. (2007b). “Learning and Time-Varying Macroeconomic Volatility.” University of California, Irvine working paper.

[29] Milani, Fabio. (2010). “Expectations Shocks ans Learning as Drivers of the Business Cycle.” University of California, Irvine working paper.

[30] Nelson, Edward. (2005). “The Great Inflation of the Seventies: What Really Happened?” *Advances in Macroeconomics* 5(1), Article 3.

[31] Nelson, Edward. (2007). “The Great Inflation and Early Disinflation in Japan and Germany.” *International Journal of Central Banking*, 3(4), 23-76.

[32] Orphanides, Athanasios. (2001). “Monetary Policy Rules, Macroeconomic Stability and Inflation: A View from the Trenches.” Finance and Economic Discussion Series 62, Board of Governors of the Federal Reserve System (U.S.).

[33] 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.

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

[35] Ozlale Umit. (2003). “Price Stability vs. Output Stability: Tales from Three Federal Reserve Administrations.” *Journal of Economic Dynamics and Control* 27, 1595-1610.

[36] Primiceri, Giorgio. (2006). “Why Inflation Rose and Fell: Policymakers Beliefs and US Postwar Stabilization Policy.” *The Quarterly Journal of Economics* 121, 867-90.

[37] Pruitt, Seth. (2010). “Uncertainty over Models and Data: The Rise and Fall of American Inflation.” mimeo, Federal Reserve Board of Governors.

[38] Romer, Christina, and David Romer. (2002). “The Evolution of Economics Understanding and Postwar Stabilization Policy.” Proceedings of the Federal Reserve Bank of Kansas City, 72-112.

[39] 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.

[40] Sargent, Thomas. (1987). Dynamic Macroeconomic Theory. Harvard University Press, Cambridge Massachusetts.

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

[42] Sargent, Thomas Noah Williams Tao Zha. (2006). Shocks and Government Beliefs: The Rise and Fall of American Inflation, *American Economic Review*, 6(4), 1193-1224.

[43] Sims, Christopher. and Tao, Zha. (2005). "Were There Regime Switches in U.S. Monetary Policy?" *American Economic Review* 96(1), 54-81.

[44] Slobodyan, Sergey Raf Wouters, (2009). "Learning in an Estimated Medium-Scale DSGE Model," CERGE-EI Working Papers wp396, The Center for Economic Research and Graduate Education - Economic Institute, Prague.

[45] Smets, Frank, and Raf Wouters. (2007). "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review* 97, 586-606.

[46] Taylor, John. (1993). "Discretion versus Policy Rules in Practice." Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

[47] Woodford, Michael. (2003). Interest and prices: Foundations of a theory of monetary policy. Princeton University Press, Princeton.

Table 1: Prior Distributions

Description	Name	Density	Mean	Standard Deviation	95% Prior Prob. Interval
IES	φ	Gamma	1.00	0.50	[0.27,2.19]
Habit formation	η	Beta	0.50	0.22	[0.09,0.90]
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	0.50	0.22	[0.09,0.90]
Infl. index wage	γ_w	Beta	0.50	0.22	[0.09,0.90]
Weight x	λ_x	Gamma	0.30	0.25	[0.02,0.95]
Weight π	λ_p	Gamma	1.00	0.50	[1.14,3.09]
Weight π^w	λ_w	Gamma	0.30	0.25	[0.02,0.95]
Weight int.smooth.	λ_i	Gamma	4.52	3.50	[0.39,13.5]
Autoregr. dem.	ρ_r	Beta	0.50	0.20	[0.13,0.87]
Autoregr. sup.	ρ_p	Beta	0.50	0.20	[0.13,0.87]
Autoregr. wag.	ρ_w	Beta	0.50	0.20	[0.13,0.87]
MP shock	σ_{mp}	InvGamma	0.40	0.1	[0.25,0.64]
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]

Table 2: Posterior Estimates

Description	Parameter	Mean	95% Posterior Prob. Interval
IES	φ	6.045	[5.359,6.695]
Habit formation	η	0.030	[0.005,0.056]
Function price stick.	ξ_p	0.120	[0.105,0.137]
Function wage stick.	ξ_w	0.0042	–
H.Econ.Inc.Price	ω_p	0.011	[0.004,0.023]
H.Econ.Inc.Wage	ω_w	1.683	[0.952,2.224]
Infl. index price	γ_p	0.008	[0.003,0.026]
Infl. index wage	γ_w	0.709	[0.672,0.742]
Weight x^1	λ_x^1	1.397	[1.073,1.560]
Weight π^1	λ_p^1	1.165	[0.864,1.460]
Weight π^{w^1}	λ_w^1	0.836	[0.484,1.206]
Weight int. smooth. ^{1}	λ_i^1	0.326	[0.234,0.384]
Weight x^2	λ_x^2	0.340	[0.297,0.376]
Weight π^2	λ_p^2	3.563	[3.284,3.853]
Weight π^{w^2}	λ_w^2	0.050	[0.004,0.276]
Weight int. smooth. ^{2}	λ_i^2	0.335	[0.310,0.353]
Autoregr. dem.	ρ_r	0.845	[0.810,0.889]
Autoregr. sup.	ρ_p	0.042	[0.018,0.091]
Autoregr. wag.	ρ_w	0.978	[0.973,0.982]
MP shock	σ_{mp}	1.356	[1.184,1.524]
Demand shock	σ_r	2.660	[1.996,3.144]
Supply Shock	σ_p	1.089	[0.973,1.167]
Wage Shock	σ_w	0.023	[0.019,0.027]
Constant Gain	$\mathbf{g}$	0.016	[0.013,0.019]

Note: ξ_w is fixed at the value estimated in Giannoni and Woodford (2005)

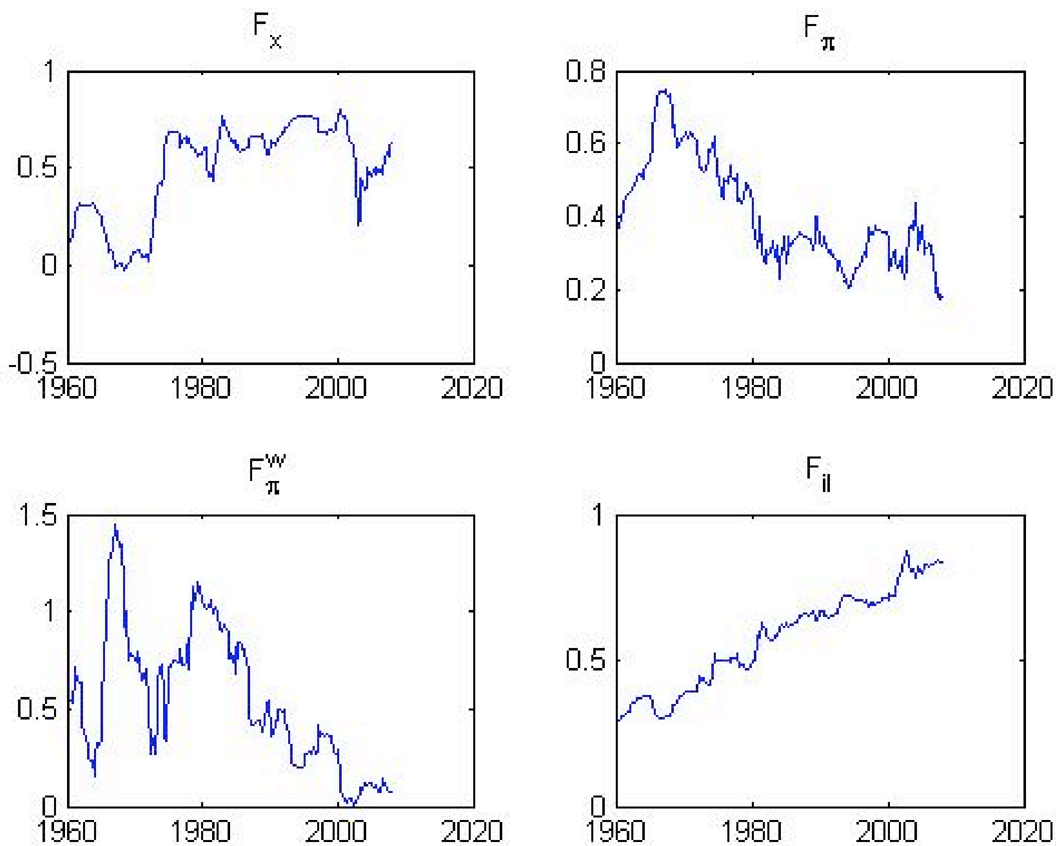

Figure 6: *(a) Output Gap, (b) Inflation, (c) Wage Inflation, and (d) Lagged Interest Rate Responses fixed to first sample weight values in the Model's Time-Varying Policy Reaction Function*

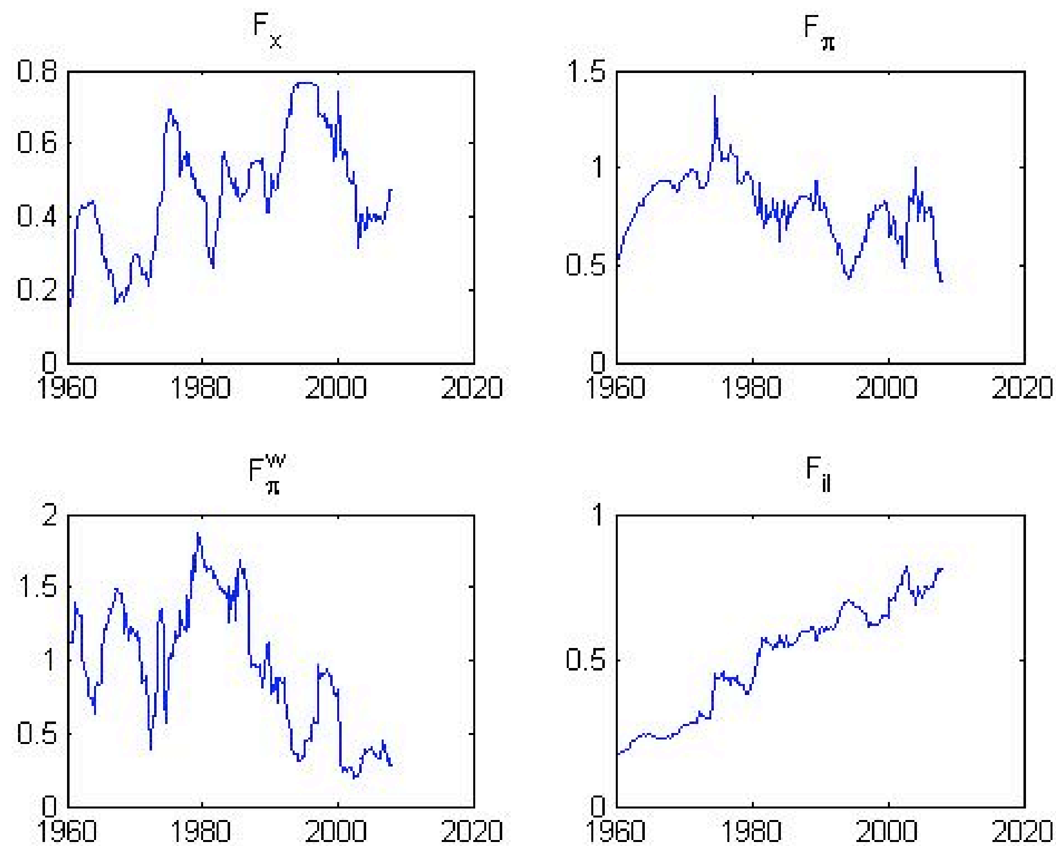

Figure 7: *(a) Output Gap, (b) Inflation, (c) Wage Inflation, and (d) Lagged Interest Rate Responses fixed to second sample weight values in the Model's Time-Varying Policy Reaction Function*

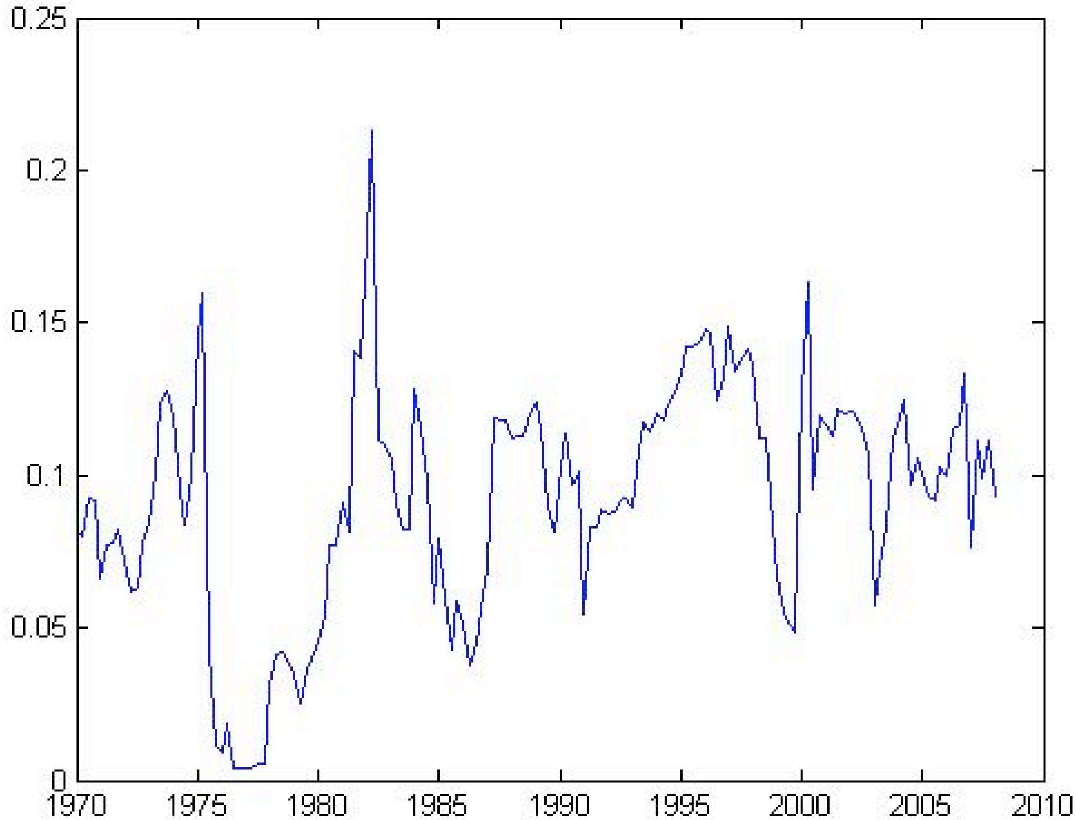

Figure 8: *Perceived Inflation Sensitivity of the Output Gap Model with 2 lags*