Essays in Monetary Economics

by

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Declarations

I, Irfan Ahmad Qureshi, declare that this thesis titled, 'Essays in Monetary Economics' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

Abstract

This dissertation examines the conduct of monetary policy, by focusing on the causes and consequences of time-varying monetary policy.

In chapter 1, I study whether money growth targeting leads to indeterminacy in the price level. I extend a conventional framework and show that the price level may be indeterminate if the central bank's response to money growth is weak even when the Taylor principle is satisfied. Based on this reasoning, policy coefficients estimated using novel Federal Open Market Committee (FOMC) meeting-level data propose a new channel of the policy mistakes that may have triggered indeterminacy during the Great Inflation. Furthermore, I show that 'passively' pursuing money growth objectives generates significantly larger welfare losses compared to alternative specifications of the monetary policy rule but 'active' money growth targeting drastically minimizes welfare loss. I confirm the relationship between pursuing money growth objectives and macroeconomic volatility using cross-country evidence.

In chapter 2, I decompose deviations of the Federal funds rate from a Taylor type monetary policy rule into exogenous monetary policy shocks and a time-varying inflation target. I show that the role of exogenous shocks may be exaggerated in a fixed inflation target model, and a large fraction of business cycle fluctuations attributed to them may actually be due to changes in the inflation target. A time-varying inflation target explains approximately half of the volatility normally attributed to these deviations, and consequently more than a quarter of the fluctuations in the business cycle. This contributes approximately 39% additional inflation volatility during the Great Inflation. I show that shocks to the inflation target imply a lower sacrifice ratio compared to exogenous changes in the interest rate and therefore propose a gradual adjustment of the inflation target in

order to achieve monetary policy objectives.

Chapter 3 presents an overview of the literature on the conduct of monetary policy. First, I summarize the design of monetary policy by differentiating between the goals, targets and instruments of monetary policy. Second, I focus on the role of policy rules as a basis for the setting of the Federal Funds rate in the U.S., and analyse the merits of including other objectives in the baseline policy rule. I study the welfare impact of these objectives in light of their historical macroeconomic performance documented in the literature. I also evaluate alternative policy rules such as constant money growth rules and nominal GDP targeting frameworks. Last, I study the classic rules versus discretion debate in light of the time-varying nature of monetary policy.

The dissertation is presented in the following order: chapter 1 presents the paper titled 'Monetarism, indeterminacy and the Great Inflation'. Chapter 2 presents the paper titled 'What are monetary policy shocks?', and chapter 3 presents a review of the literature on the conduct of monetary policy.

Abbreviations

AIC Akaike Information Criterion

AR Autoregessive

ARMA Autoregessive Moving Average

BIC Bayesian Information Criterion

CBO Congressional Budget Office

DGLS Dynamic Generalized Least Squares

DOLS Dynamic Ordinary Least Squares

D.S.G.E Dynamic Stochastic General Equilibrium

Fed Board of Governors of the Federal Reserve System

FFR Federal Funds Rate

FOMC Federal Open Market Committee

FRED Federal Reserve Economic Data

GDP (Real) Gross Domestic Product

IID Independent and identically distributed

IG Inverse Gamma

M1 Sum of currency held by the public and transaction deposits at depository institutions (Fed definition).

M2 M1 plus savings deposits, small-denomination time deposits (Fed definition).

MA Moving Average

ML Maximum Likelihood

MLE Maximum Likelihood Estimation

NGDP Nominal Gross Domestic Product

OMO's Open Market Operations

SOMA System Open Market Account

TV Time-varying

U.S The United States of America

Chapter 1

Monetarism, Indeterminacy and the Great Inflation

1.1 Introduction

The dramatic rise in the volatility of output and inflation experienced by the U.S. economy during the 1960s and 1970s followed by a substantial reduction in the 1980s, has been a source of significant debate. Particular attention has been given to examining the role of monetary policy in generating this Great Moderation in macroeconomic activity. Clarida et al. [2000] suggest that the inability of the Federal Reserve ('the Fed') to raise nominal interest rates more than one-for-one with inflation, that is, satisfy the Taylor [1999] principle, induced self-fulfilling expectations-driven fluctuations. This caused price level indeterminacy, leading to macroeconomic instability. Volcker marked his appointment as Chairman of the Fed with a strong response to inflation and a switch from a 'passive' to an 'active' policy rule, ensuring price equilibrium determinacy and a subsequent increase in macroeconomic stability.

Yet evidence presented by Orphanides [2002] using the Federal Open Market Committee's (FOMC) meeting level data did not detect large changes in the Fed's response to inflation when comparing the period before and after Volcker's

appointment. This has raised questions about how monetary policy contributed to the difference in macroeconomic instability observed between the two periods. Since under these policy rules a strong response to inflation is not a sufficient condition of active policy, other policy objectives may also have had a part in achieving price equilibrium determinacy. For example, previous work illustrating the behaviour of monetary policy during the 1970s ignores the impact of M1 targeting[1] as a possible channel that may have induced passive policy despite the FOMC's strong response to inflation.

Although M1 targeting[2] was never a formal policy goal, during the committee meeting of January 1970 the FOMC decided that '[an] increased stress should be placed on the objective of achieving modest growth in the monetary aggregates'. The policy directive from the second FOMC meeting instructed the manager of the System Open Market Account (SOMA) to 'seek first and foremost a pattern of growth in a subset of monetary aggregates', and to maintain 'money-market conditions consistent with this objective'.[3] The FOMC paid close attention to growth in monetary aggregates as possible information variables, as discussed in Mishkin [2007b]. In effect, the FOMC acted as if controlling M1 was an objective of monetary policy, and directed the SOMA manager to steer the Federal funds rate to keep its money growth objectives on track (see, for example, Kane [1974], Meulendyke [1988], Larkin et al. [1988] and Friedman [1996]). Empirical evidence of this change in objectives has been presented in DeRosa and Stern [1977], wherein M1 is detected to have influenced the setting of interest rates in the early 1970s, compared to its less significant role during the late 1960s.

It is plausible, then, that a change in M1 objectives shifted monetary policy from active to passive and triggered indeterminacy, irrespective of the FOMC's relatively strong response towards inflation, explaining the conflicting conclusions

[1] I use the terms M1 targeting, intermediate targeting of money, M1 growth targeting, monetarism and pursuit of money growth objectives interchangeably.

[2] Although the Fed set targets for the growth of three different monetary aggregates, the centre of attention was the narrow money stock, M1 (Friedman [1996]).

[3] For example, the Federal funds rate and discount window borrowing (Karamouzis and Lombra [1989]).

presented in Clarida et al. [2000] and Orphanides [2002]. The increase in macroeconomic instability observed during the Great Inflation could be attributed to the incompatibility of the Fed's money growth (M1) objectives with its other goals which, when finally abandoned under Chairman Volcker, gradually shifted the U.S. economy towards determinacy. However, macroeconomic consequences of this monetary policy regime have not been studied due to a lack of evidence of M1 targeting within a Taylor type rule using real-time data.

In this paper, I investigate the contribution of money growth as an objective of monetary policy. Specifically, I focus on the macroeconomic instability that pursuing this type of policy generates, using the U.S. as a case study. First, I derive theoretical conditions that pin down price level equilibrium in a standard New Keynesian model. In this environment, price level determinacy depends on the monetary policy response coefficients and on the behaviour of money demand. Second, I use novel meeting-level FOMC data on M1 growth to provide novel empirical evidence of changes in the objectives of monetary policy. Third, I combine my theoretical and empirical results to capture the contribution of changes in policy objectives to the instability in the US economy. I show that this policy may have generated a significant welfare loss in steady state consumption, giving a raison d'être for the Fed's switch from targeting M1 in the early 1980s.

I offer a new perspective on the impact of money growth objectives and the money demand relationship on price level determinacy. I show that when the policy reaction function contains a money growth objective, the relationship between nominal money and inflation contributes to the likelihood of determinacy, operating independently of the relationship between nominal money, output and the interest rate. Alternatively, when the nominal money and inflation channel is stable, a weak response to money growth also triggers indeterminacy, irrespective of whether the Taylor principle is satisfied. A key implication of this result is that under these two scenarios, it may be desirable for the monetary authority to switch to an inflation-targeting regime to achieve price level determinacy. The price level

determinacy results derived in this paper extend the results presented in Keating et al. [2014] by highlighting the critical relationship between nominal money and inflation in ensuring price level determinacy when the monetary authority pursues money growth objectives.

Second, I use extended FOMC data on M1 growth[4] to estimate a time-varying monetary policy rule from 1970 through to 1987. By allowing monetary targets to enter as an objective of policy, my empirical evidence highlights a unique type of loose and volatile monetary policy, which is quite different from that implied in Orphanides [2002] and Boivin [2005]. The coefficient on M1 is estimated to be statistically significant from 1970 to late 1974, and from 1979 through to late 1981, which is consistent with the observation that the FOMC under Chairman Burns paid more attention to money growth in the early 1970s (Burns [1979], and Sims and Zha [2006]). Additionally, the negative coefficient on M1 is consistent with the findings of Benati and Mumtaz [2007], Friedman [1996], and Friedman et al. [1996] from 1979 through to 1981. The negative coefficient on money growth is also consistent with the findings of Canova and Menz [2011]. Compared to Coibion and Gorodnichenko [2011] and Boivin [2005], the coefficient on inflation is marginally lower, falling gradually throughout the sample and rising sharply in the 1980s. Simliar to their findings, this coefficient is greater than one for the entire sample.

To test the likelihood of the US economy being in a determinate equilibrium from 1970 through to 1987, I combine the empirical distribution of the estimated policy and money demand coefficients with a parameterized New Keynesian model. My results suggest a high likelihood of indeterminacy during the first half of the 1970s and during Volcker's deflation, and a high likelihood of price level determinacy from the 1980s. These results are closer to the implications forwarded by Clarida et al. [2000], and Coibion and Gorodnichenko [2011] than the conclu-

[4] A quarter of the series from 1970 - 1975 is taken from Kozicki and Tinsley [2005], while the rest of the series from 1976 through to 1987 is collected from policy directives and the Greenbook forecasts. The FOMC stopped setting M1 targets during the second meeting of 1987.

sions reached by Orphanides [2002], and suggest that the monetary policy reaction function is the primary driving factor generating price level indeterminacy during the Great Inflation. Contrary to their framework, I show that the weak response to money growth mitigates the relatively strong response to inflation, rendering monetary policy passive and triggering indeterminacy.

Last, I consider the role of monetary growth objectives as a potential source of the additional macroeconomic volatility observed during the 1960s and the 1970s, and present welfare-based evidence in support of a switch to a Taylor type policy rule. My findings suggest that a sizeable portion of the reduction in macroeconomic volatility in the 1980s may be attributed to monetary policy. I show that the countries that pursue money growth objectives equivalent to the U.S are found to have significantly higher output and inflation volatility as compared to countries that pursue only inflation as an objective of policy. In light of the theoretical and empirical findings of this paper, countries that pursue money growth objectives similar to the U.S may attain significant welfare gains by switching to a Taylor type specification.

To my knowledge, this paper is the first to formalize the critical role played by money in FOMC policy formulations using meeting-level data, and analyse its impact on historical macroeconomic instability. The specific channel analysed in this paper provides additional support for the well-known view that changes in monetary policy may have played an important role during the Great Inflation. In general, these findings contribute both to the classic papers by Clarida et al. [2000], Orphanides [2002], Taylor [1999], and to the recent papers by Coibion and Gorodnichenko [2011], Boivin [2005] and Lubik and Matthes [2014]. To answer this question, I make a number of important empirical and theoretical contributions.

First, the novel price determinacy conditions under money growth targeting contribute to the theoretical literature which has focused mainly on the response towards inflation as a pre-requisite of active policy (Friedman [2000], Woodford [2001], Carlstrom and Fuerst [2003]) and builds on the results by Keating et al.

[2014]. While it is well-known that money demand stability plays an important role when a central bank targets money, this paper is the first to propose its influential role in generating price indeterminacy. This finding has broad theoretical appeal for the literature focusing on price determinacy, and for the recent literature examining monetary policy and the quantity theory (Sargent and Surico [2011], Teles et al. [2016]). These results also contain practical lessons for central banks that target money.

Second, my empirical results formalize the central role of money in FOMC policy deliberations using novel real-time data, extending the evidence provided in Burns [1979], Sims and Zha [2006], Benati and Mumtaz [2007], Friedman [1996], Clarida et al. [2000], Orphanides [2002], Boivin [2005] and Coibion and Gorodnichenko [2011]. My central finding, which suggests that the US economy experienced price indeterminacy during the 1970s, supports the implications put forward by Clarida et al. [2000], and Coibion and Gorodnichenko [2011]. An important aspect of my results also proposes analysing the U.S. economy in distinct phases, since multiple determinacy-indeterminacy regimes appear to have occurred during the 1970s. This finding is closer to the results conjectured by Sims and Zha [2006], Boivin [2005], Bianchi [2012] and Lubik and Matthes [2014], and differs from the classic pre-and-post-Volcker analysis of Clarida et al. [2000] and Orphanides [2002].

The quantitiative results presented in this paper also suggest that a sizeable portion of the reduction in macroeconomic volatility in the 1980s may be attributed to monetary policy. In this context, my results support the claims made by Roberts [2006], Leduc and Sill [2007] and Taylor [2013] on the role of policy parameters in generating the change from macroeconomic instability to stability. However, the specific reason highlighted in this paper attributes this change to the time-varying response towards money aggregates.

These results may also contribute to the recent surge in the literature investigating the role of money in describing the macroeconomy (see, for example, Favara and Giordani [2009], Canova and Menz [2011] and Castelnuovo [2012a]).

Using a DSGE model with money, Castelnuovo [2012a] has concluded that money plays an active role in explaining the U.S. macroeconomic dynamics during the pre-Volcker sample. Contrary to his findings, I show that the FOMC trageted M1 during the 1970s. This is verified by extensively studying the narrative record based on the transcripts of the FOMC. The parsing is critical in understanding the evolution of the role of different money aggregates as a policy objective from 1970s onwards. From a policy perspective, this paper outlines an alternative benchmark to conduct and evaluate monetary policy, extending the classic result of Taylor [1993]. As highlighted in the final section of this paper, this result may have relevance for countries that continue to target money as a policy objective.

An obvious drawback of this study is that it ignores other potential explanations for the Great Inflation, such as those related to fiscal theory of the price level (see, for example, Leeper [1991], Sims [1994]).[5] This framework also ignores other methods of introducing money in DSGE models, such as both explicitly incorporating money in the utilty framework (Castelnuovo [2012b]), as well as through portfolio adjustment costs (Andrés et al. [2009]). Finally, while the imposition of rational expectations allows me to utilize the simplest model for monetary policy analysis, it has been criticisized especially when analyzing determinacy of Taylor Rules. For example, setting the interest rate based only on exogenous fundamental variables leads to instability problems if in fact private agents do not a priori have rational expectations (RE) but instead form expectations using standard adaptive learning rules. This was recently demonstrated by (Evans and Honkapohja [2003a]) in the context of the New Keynesian model that has become a standard framework in recent research on monetary policy

[5]Specifically, Cochrane [2007] argues that the central bank's response to inflation will be unidentified in New Keynesian models when the Taylor rule includes a stochastic intercept term that corresponds to the natural rate of interest, i.e., the rate of interest that would hold in the frictionless economy. However, Sims [2008] shows that Cochrane's argument holds only if the central bank is responding one-for-one to fluctuations in the natural rate of interest, an unlikely scenario due to the inherent difficulty in measuring the natural rate of interest, particularly in real time. More generally, the Fed may be stabilizing inflation with off-equilibrium path threats that may not be observed in equilibrium. However, in practice, periods of apparent indeterminacy in the policy rule have come when trend inflation is high. Thus it is highly unlikely that the Fed has effectively been using off-equilibrium strategies over this period to stabilize inflation.

In the next section I outline the model, the determinacy conditions implied by a monetary policy rule with money growth objectives, and the baseline parameterization. Section 1.2 presents empirical evidence of money growth objectives using a time-varying specification, and estimates of a money demand curve, which are then used to calculate the likelihood of determinacy. The contribution to macroeconomic volatility, and the welfare loss implied by each monetary policy specification, is also enumerated. In section 1.4, I present international evidence of monetary aggregate targeting. Section 1.5 concludes, with suggestions for future research.

1.2 Model, Parameterization and Determinacy

To derive the conditions that pin down price level determinacy under a policy rule which contains a money growth objective, I utilize a prototypical New Keynesian DSGE model developed by Walsh [2003a], Gali [2009] and Woodford [2011]. This model is a suitable baseline framework for analyzing monetary policy due to the presence of staggered pricing.

1.2.1 The Structural Model

Two equations, a dynamic Phillips curve and the dynamic IS curve, are derived from the optimality conditions of a continuum of household and firms:

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) + g_t \tag{1.1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \tag{1.2}$$

where π_t is inflation and x_t is the output gap.[6] Equation 1.1 is the log-linearized Euler condition, where the output gap is negatively related to the difference between the nominal interest rate, i_t, and positively related to expected

[6] Lowercase letters denote the natural logs of the corresponding variable as presented in (Gali [2009]).

inflation, π_{t+1}. Due to the intertemporal substitution effect, higher real returns induce greater savings, depressing aggregate demand. Expectations of a positive output gap expand the current output gap, as economic agents prefer to smooth their consumption. Since the underlying model has no investment, output is proportional to consumption in equilibrium. Aggregate output is subject to a shock g_t that can be interpreted as a shock to government spending, or as a shock to the household preferences. Equation 1.2 is the New-Keynesian Phillips curve (NKPC), which relates inflation in the current period to expectations of inflation and the output gap. In the NKPC, β is the discount factor, and κ is a convolution of the structural parameters which include a Calvo [1983] style staggered pricing mechanism. u_t represents an exogenous cost-push shock, such as those related to unexpected changes in oil prices. To track money, I use an extended money demand equation from Stock and Watson [1993]:

$$m_t^n = \eta_\pi p_t + \eta_x y_t - \eta_i i_t + \tau_t \tag{1.3}$$

Similar to Mehra [1991] and Söderström [2001], I take first differences to obtain an expression for the growth rate of the nominal money stock:

$$\Delta m_t^n = \eta_\pi \pi_t + \eta_x \Delta y_t - \eta_i \Delta i_t + \Delta \tau_t \tag{1.4}$$

Δm_t^n is the log change in the nominal money stock and Δy_t is growth in actual output. τ_t captures exogenous money demand shocks and η_j for $j \in (\pi, i, y)$ represents the (semi-)elasticity of nominal money growth of each of these variables. Based on the implications of the quantity theory of money η_π is generally normalized to one, but this relationship may change over time.[7] With this equation I can track short run departures from traditional money demand relationships between nominal money, inflation, interest rates and output (see for example Lucas [1980]).

I close the model with a monetary authority that sets the nominal interest

[7]This argument has also been considered in Stock and Watson [1993], who test if $\eta_\pi = 1$ using annual and quarterly U.S. data using equation 1.3.

rates. The baseline specification for the monetary policy reaction function is a generalized Taylor rule, and includes a response to growth in broad monetary aggregates such as M1. Money growth objectives may be linked with policy goals in the long run, but with short-run deviations in these relationships. In this sense, the nominal rate may be adjusted when growth in money is exceeding or falling from a long run target (see, for example, Meulendyke [1988], Larkin et al. [1988] and Karamouzis and Lombra [1989]).[8] Consequently, a meeting-specific feedback rule which captures the forward-looking behaviour of the Fed can be written:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi,t} E_t \pi_{t+j} + \psi_{x,t} E_t x_{t+j} + \psi_{m,t} E_t \Delta m^n_{t+j}] + c_t + \epsilon_t \tag{1.5}$$

for $j \in (0, 1, ..)$; ϵ_t is an error term. I compare this baseline case with Coibion and Gorodnichenko [2011], under which the reaction function takes the following functional form:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi} E_t \pi_{t+j} + \psi_{x} E_t x_{t+j} + \psi_{gy} E_t gy_{t+j}] + c_t + \epsilon_t \tag{1.6}$$

The structural shocks, g_t, u_t, and τ_t and the exogenous policy shock ϵ_t are all assumed to follow a mean zero AR(1) process, characterized by persistence ρ, and shock variance, σ.

[8] On the operational side, the target range of interest rate is decided during an FOMC meeting, directing the System Open Market (SOMA) manager to adjust security transactions in order to maintain the interest rate within that range (Kane [1974]). During the 1970 - 1979 period, the operating target was the federal funds rate, and nominal money aggregates played a role in influencing the setting of this policy rate, in order to keep monetary policy consistent with long run objectives. In this setting, the Federal funds rate is determined by the position of the bank reserves, which combined with the cash in the economy times the money multiplier gives an estimate of money supply. It has been argued that broad money growth is not perfectly under the control of the monetary authority, and the large fluctuations in money demand must be accommodated, Goodhart [1994].

1.2.2 Equilibrium Determinacy Under Money Growth Objectives

To study the equilibrium properties of the baseline monetary policy rule when the central bank responds to inflation, output and to a broad measure of a monetary aggregate, I derive the price level determinacy conditions.[9] First, I derive a baseline price level determinacy condition for the general policy rule, and then focus on the different combinations of simple rules.

A General Determinacy Condition

Under the baseline rule, the conditions outlined in Woodford [2011] can be used to derive the necessary and sufficient condition that guarantees price level determinacy:

Proposition 1: Determinacy condition for rules with money growth objectives *For any $\beta \in (0,1)$, and any $\kappa > 0$, if the monetary authority follows the policy rule $i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1-\rho_1-\rho_2)(\psi_\pi E_t \pi_{t+j} + \psi_x E_t x_{t+j} + \psi_{\Delta m} E_t \Delta m^N_{t+j})$, the following conditions are sufficient for determinacy:*

$$(\beta\sigma)^{-1}(\delta_4(1-\beta) + \kappa(\delta_3 - 1) + \delta_5(1-\beta) + (\delta_1+\delta_2)\kappa) > 0 \tag{1.7}$$

$$-(\beta\sigma)^{-1}((\delta_4-\delta_5)(1+\beta) + \kappa\delta_3 + (\delta_1-\delta_2+1)(\kappa+2\sigma+2\beta\sigma)) < 0 \tag{1.8}$$

where δ_i for $i \in \{1,2,3,4,5\}$ are convolutions of the policy parameters and

[9] One may question whether commitment to an interest rate rule of this kind, incorporating no target path for any monetary aggregate, can serve to determine an equilibrium price level at all. According to the well-known critique of Sargent and Wallace [1975], interest rate rules as such are undesirable, as they lead to indeterminacy of the rational expectations equilibrium price level. However, their analysis assumes a rule that specifies an exogenous path for the short-term nominal interest rate; determinacy is instead possible in the case of feedback from an endogenous state variable such as the price level, as noted by McCallum [1981]. In fact, many simple optimizing models imply that the Taylor rule incorporates feedback of a sort that suffices to ensure determinacy, owing to the dependence of the funds rate operating target upon recent inflation and output-gap measures.

structural parameters underlying the transmission mechanism:

$$\delta_1 = \frac{\rho_1 + \eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)}{1+\eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)} \qquad \delta_2 = \frac{\rho_2}{1+\eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)}$$

$$\delta_3 = \frac{(1-\rho_1-\rho_2)(\psi_\pi + \eta_\pi \psi_{\Delta m})}{1+\eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)} \qquad \delta_4 = \frac{(\eta_x \psi_{\Delta m} + \psi_x)(1-\rho_1-\rho_2)}{1+\eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)}$$

$$\delta_5 = -\frac{\eta_x \psi_{\Delta m}(1-\rho_1-\rho_2)}{1+\eta_i \psi_{\Delta m}(1-\rho_1-\rho_2)}$$

Proof: See appendix

Next, I discuss price level determinacy under various combinations of the monetary policy rule.

Responding to Output Gap and Inflation

Assume first that the monetary authority only responds to contemporaneous inflation and the output gap. This familiar policy rule can be written:

$$i_t = \psi_\pi \pi_t + \psi_x x_t \tag{1.9}$$

The necessary and sufficient conditions under this policy rule can be obtained by setting $\psi_{\Delta m}$, ρ_1 and ρ_2 equal to zero in condition 1.7.[10]

$$(1-\beta)\psi_x + \kappa(\psi_\pi - 1) > 0 \tag{1.10}$$

As discussed in Gali [2009] and Woodford [2011] this feedback rule satisfies the Taylor principle since it implies that in the event of a sustained increase in the inflation rate of k percent, the nominal interest rate will eventually be raised by more than k percent. In particular, the coefficient values associated with the classic Taylor [1993] rule ($\psi_\pi = 1.5$, $\psi_x = 0.5$) necessarily satisfy the criterion, regardless of the size of β and κ. Thus feedback from the Taylor rule suffices to determine an equilibrium price level.

[10] We can ignore the second determinacy condition for this case, since expression 2.5 will boil down to a condition where the sum of two positive policy parameters and three structural parameters (which are positive by assumption).

Responding to Money Growth and Inflation

To analyze price level determinacy conditions when the monetary authority responds to contemporaneous inflation and money growth, the following policy rule is considered:

$$i_t = \psi_\pi \pi_t + \psi_{\Delta m} \Delta m_t^N \tag{1.11}$$

Setting ρ_1, ρ_2, and ψ_x equal to zero in condition 1.7 yields the following novel proposition:

Proposition 2: Extension of the Taylor principle *For any $\beta \in (0,1)$, and any $\kappa > 0$, $\eta_i \geq 0$ and $\eta_x \geq 0$, if the central bank follows the simple rule $i_t = \psi_\pi \pi_t + \psi_{\Delta m} \Delta m_t^N$, this condition is sufficient for determinacy:*

$$\eta_\pi \psi_{\Delta m} + \psi_\pi > 1 \tag{1.12}$$

Thus, the likelihood of determinacy is affected by the response to money growth and the stability in the relationship between nominal money and inflation irrespective of the Taylor principle being satisfied. Setting $\psi_{\Delta m} = 0$, for any parameterization of the money demand, or setting the money demand to zero for any parameterization of $\psi_{\Delta m}$, condition 1.12 collapses to the Taylor principle:

$$\psi_\pi > 1 \tag{1.13}$$

Therefore, under condition 1.13, the monetary authority should switch its focus to inflation in order to guarantee price level determinacy when the money demand relationship has become unstable, or when the monetary authority is unable to respond sufficiently strongly to money growth.

Next, I focus on the general price level determinacy condition, in equation 1.12. To consider the implications for the nominal rate under the policy rule

specified in equation 1.11, assume a permanent increase in inflation of size $d\pi$:

$$di = \psi_\pi d\pi + \psi_{\Delta m} d\Delta m \tag{1.14}$$

Simplifying the money demand relationship described in equation 1.3, the change in the nominal interest rates can be captured by:

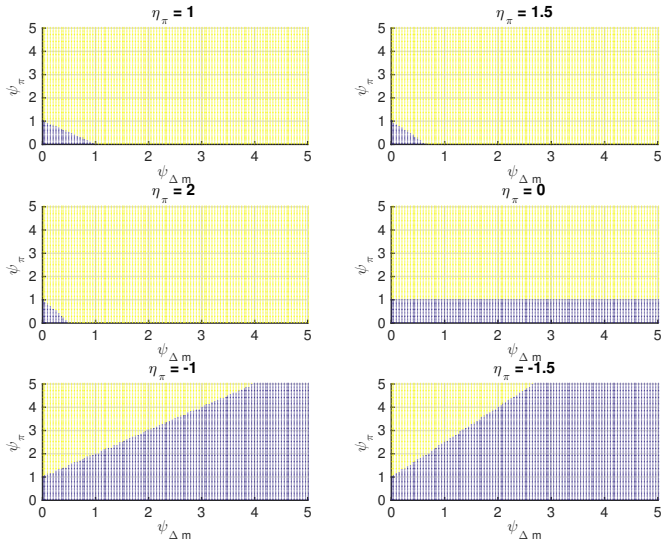
$$di = (\psi_\pi + \eta_\pi \psi_{\Delta m}) d\pi \tag{1.15}$$

Condition 1.12 is equivalent to the term in brackets in equation 1.15 being greater than one, implying that the price level equilibrium will be unique under interest rate rule 1.11 whenever ψ_π and $\psi_{\Delta m}$ are sufficiently large (or are of the same sign) to guarantee that the real interest rate rises in the face of an increase in inflation of size $d\pi$. Moreover, since price level determinacy depends on the cumulative response to money growth and inflation, the response to money growth only matters relative to the response to inflation. This is important since interest rates may respond negatively to money growth, as empirically estimated in Friedman [1996] and Benati and Mumtaz [2007]. When nominal money growth and inflation are characterized by a unitary relationship (i.e., when $\eta_\pi = 1$), and the monetary authority chooses to respond only to money growth, then $\psi_{\Delta m} > 1$ also guarantees determinacy, since real interest rates rise more than inflation according to equation 1.18. This condition is similar to the determinacy condition outlined in Keating et al. [2014], but is generalized to allow for variation in η_π.

The determinacy regions under multiple parameterizations of η_π are shown in Figure 1.1. First, when $\eta_\pi \in (0, 1)$ the determinacy region shrinks, since the relationship between nominal money and inflation deteriorates. Only a greater response to money growth mitigates this channel, conditional on the same response towards inflation. For $\eta_\pi > 1$, the central bank benefits from the stable transmission mechanism. Given the same response towards inflation, a relatively lower response towards money growth is required to achieve price level determinacy.

When η_π is negative, a stronger response towards inflation,[11] or the opposite sign on money growth would be required to guarantee price level determinacy. Critically, when η_π is restricted to zero, then any response to monetary growth does not guarantee determinacy and only a strong response to inflation, of magnitude greater than one (i.e. the Taylor principle), can guarantee price level determinacy. These results differ from Keating et al. [2014], as the relationship between nominal money and inflation is crucial for determinacy, and plays an important role even when the relationship between nominal money, output, and interest rates is stable or unstable.[12]

Figure 1.1: Determinacy Regions when η_π is allowed to vary



This figure presents determinacy regions based on the feedback rule where the central bank responds to inflation and monetary growth. The plots consider the effect on the determinacy region when the relationship between nominal money growth and inflation is allowed to vary. The (dark) shaded blue area represents the indeterminacy regions.

[11]Specifically, the response needs to be of magnitude $1 + \eta_\pi \psi_{\Delta m}$.

[12]Note that the determinacy conditions studied in this section are based on the restriction $\eta_i \geq 0$, $\eta_x \geq 0$, and which includes the scenario where these relationships might break down (i.e., when $\eta_i = 0$ and $\eta_x = 0$).

Interest Rate Smoothing

Last, I analyze the case where the monetary authority responds to contemporaneous money growth and partially smoothes interest rates. Clarida et al. [1998] show that incorporating a partial-adjustment mechanism to the original Taylor [1993] rule helps improve the fit of the actual variation in the nominal interest rate observed in the U.S economy and some large European economies. This is a weighted average between lagged nominal interest rate and the Taylor-type targeting rate, and can be extended to explore the determinacy conditions when the monetary authority only pursues money growth objectives:

$$i_t = \rho_1 i_{t-1} + \psi_{\Delta m} \Delta m_t \tag{1.16}$$

Proposition 3: Money targeting and interest rate smoothing *For any $\beta \in (0,1)$, and any $\kappa > 0$ if the central bank follows the simple rule $i_t = \rho_1 i_{t-1} + \psi_{\Delta m} \Delta m_t$, the following condition is sufficient for determinacy:*[13]

$$\psi_{\Delta m} + \rho_1 > 1 \tag{1.17}$$

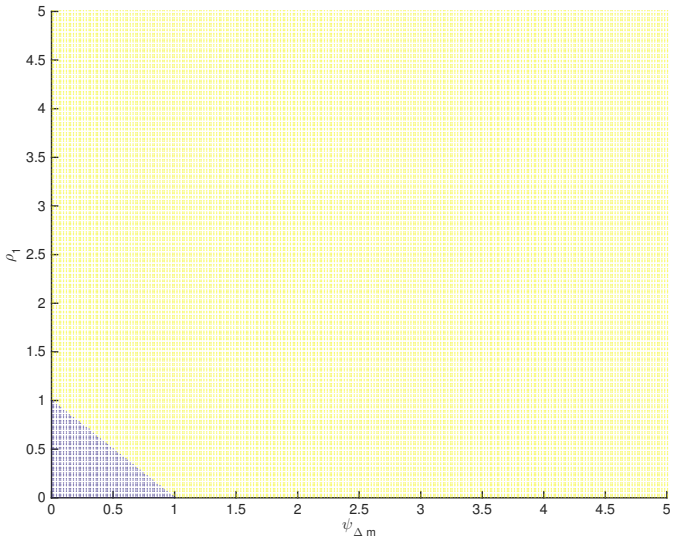
This result can be obtained by setting ρ_2, ψ_x and ψ_π equal to zero in equation 1.7. As before, consider the implications for the nominal rate under the monetary policy rule defined in equation 2.16 if there was a permanent increase in inflation of size $d\pi$.

$$di = \frac{\psi_{\Delta m}}{1 - \rho_1} d\Delta m \tag{1.18}$$

If condition 1.17 is satisfied, then the condition $\frac{\psi_{\Delta m}}{1-\rho_1}$ is greater than one, and is enough to guarantee that the real interest rises in the face of an increase in inflation. This tends to counteract the increase in inflation of magnitude $d\pi$, and acts as a stabilizing force. Figure 1.2 plots the determinacy region for this result.

[13] For the remainder of this section, I assume a stable money demand relationship, since the case where the relationship is unstable follows exactly the same intuition discussed in the previous subsection.

Figure 1.2: Determinacy Regions under Interest Rate Smoothing



This figure presents determinacy conditions based on the feedback rule where the central bank responds only to money growth, and under partial interest rate smoothing. The (dark) shaded blue area represents the indeterminacy region.

1.2.3 Parameterization

The baseline parameterization of the model takes the relevant value to correspond to a quarter, and primarily relies on the values presented in Gali [2009]. β is set to 0.99 which is standard in the literature on business cycle models in the U.S. I assume that households' preferences can be represented by a log utility function, which implies $\sigma = 1$ and unitary Frisch elasticity, $\varphi = 1$, $\alpha = 1/3$ and $\epsilon = 6$. The average price duration is assumed to be three quarters, which implies that $\theta = 2/3$. The money demand function, the parameters η_π, η_x and η_i are all normalized to one in the baseline case. The parameters for the exogenous shocks, cost-push, productivity and monetary policy are taken from the estimation in Smets and Wouters [2007] for the 1984 through to the 2004 sample, and the aggregate demand shock is calibrated with the value used by Lubik and Schorfheide [2004]. Finally, the money demand shock is parameterized with the value discussed in Gali [2009]. Table 1.1 summarizes the baseline parameterization, split into structural and shock

parameters, which are used to simulate the model.

Table 1.1: Baseline Parameterization

Structural			Shocks		
Parameter	Value	Source	Parameter	Value	Source
β	0.99	Gali [2009]	ρ_a	0.94	Smets and Wouters [2007]
σ	1	Gali [2009]	ρ_v	0.29	Smets and Wouters [2007]
φ	1	Gali [2009]	ρ_g	0.7	Lubik and Schorfheide [2004]
α	1/3	Gali [2009]	ρ_u	0.74	Smets and Wouters [2007]
ϵ	6	Gali [2009]	ρ_τ	0.6	Gali [2009]
θ	2/3	Gali [2009]	σ_a	0.35	Smets and Wouters [2007]
η_x	1	Gali [2009]	σ_v	0.12	Smets and Wouters [2007]
η_i	1	Gali [2009]	σ_g	0.38	Lubik and Schorfheide [2004]
η_π	1	Gali [2009]	σ_u	0.11	Smets and Wouters [2007]
			σ_τ	0.63	Gali [2009]

The table presents the baseline parameterization of the model. All values are adapted to the quarterly frequency of the model.

1.3 Monetary Growth Objectives during the 1970s

In this section, I construct the likelihood of the U.S. economy being in a determinate equilibrium. I combine the theoretical determinacy conditions with empirical estimates of the policy rule, beginning with estimating a time-varying parameter version of the baseline monetary policy reaction function. Since money demand parameters influence determinacy in this framework, I also estimate a generalized version of the money demand curve. I combine these empirical results with the theoretical determinacy conditions to assess the implications on price level equilibrium. This captures the contribution of changes in monetary policy objectives that may have moved the economy into an indeterminate equilibrium during the Great Inflation: after this policy was abandoned under Chairman Volcker the economy shifted back to a determinate equilibrium. Last, I show that pursuing money growth objectives generated high macroeconomic volatility, and therefore significantly higher welfare losses, than would have occurred under a Taylor type

specification.

1.3.1 Empirical Evidence

Estimating the Monetary Policy Reaction Function

My baseline specification for the FOMC's reaction function is a generalized Taylor rule. This interest rate rule allows for interest smoothing of order two, a response to inflation, output gap and nominal money growth.

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi,t}\pi_t + \psi_{x,t} E_t x_t + \psi_{m,t}\Delta m_t] + c_t + \epsilon_t \quad (1.19)$$

To estimate this equation, I use Greenbook forecasts of current and future macroeconomic variables prepared by staff members of the Fed prior to each FOMC meeting. For M1 growth, I use the series from 1970 through to 1975 presented in Kozicki and Tinsley [2005], while the remainder of the series from 1975 through to 1987 is from the policy directives issued at the end of the FOMC meeting, and from the Minutes.[14] The interest rate is the target Federal funds rate set at each meeting; the measure of the output gap and inflation is based on Greenbook forecasts, presented in Orphanides [2002]. I use a time-varying approach to estimate the policy coefficients, which closely follows the techniques introduced in Boivin [2005]. I assume that each of the policy parameters is time-varying and follows a driftless random walk:[15]

$$\Omega_t = \Omega_{t-1} + \omega_t \quad (1.20)$$

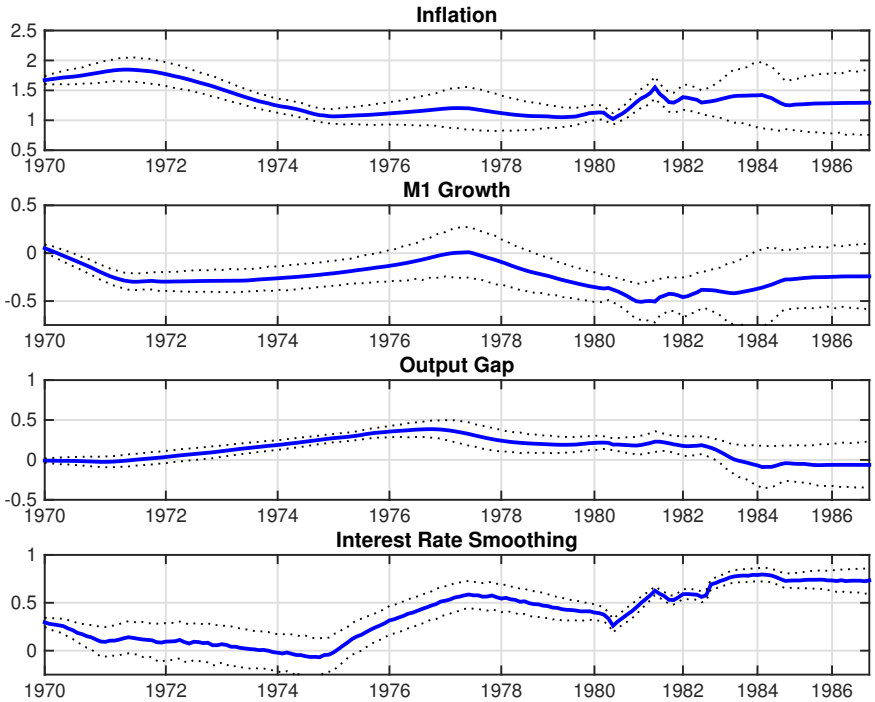
Similar to Boivin [2005], and Coibion and Gorodnichenko [2011], I allow for two breaks to accommodate the difference in volatility of the shocks during the two

[14] The FOMC stopped setting targets for M1 in 1987, so my data sample ends on this date.

[15] To deal with any possible endogeneity issues, IV estimates are included in the appendix. Moreover, numerous tests were performed on meeting-level data to gauge the likelihood of collinearity. Similar to earlier literature, I find no concerns that may influence my baseline estimates. Second, I also compile a data set for M2 based on Greenbook/Policy directives, and repeat this estimation. M2 enters with a positive sign. These results are available upon request.

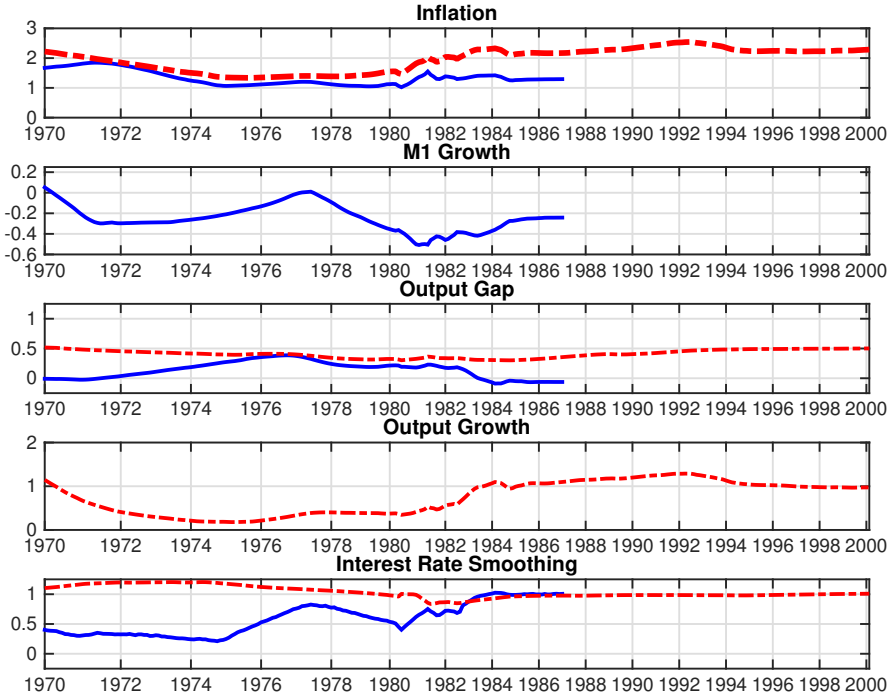
periods, with one break in 1979 and the other in 1982. For comparison, I also estimate the alternate case where the FOMC responds to output growth instead of money growth. Figures 1.3 and 1.4 present the results.

Figure 1.3: Baseline Estimates of the Reaction Function



The figure presents the time-varying estimate of the reaction function from 1970 through to 1987. The solid blue line plots estimates of the policy coefficients, while the dotted black line plots standard errors. From the top, the first panel plots the coefficient on inflation, the second panel plots the coefficient on money growth, and the third panel plots the coefficient on output gap. The last panel plots the sum of the coefficients on the first and second lag of interest rates.

Figure 1.4: Estimated Reaction Function compared with Coibion and Gorodnichenko [2011]



The figure presents the time-varying estimate of the reaction function from 1970 through to 2000. The solid blue line plots estimates from the policy rule with money growth, while the dashed red line plots estimates with output growth. From the top, the first panel plots the coefficient on inflation, the second panel plots the coefficient on money growth, the third panel plots the coefficient on output gap, and the fourth panel plots the coefficient on output growth. The last panel plots the sum of the coefficients on the first and second lag of interest rates.

The estimated coefficients suggest that monetary policy during this period was procyclical, loose and volatile, and provides a unique interpretation of the policy mistakes observed during the Great Inflation. First, the weight on money growth is estimated to be negative throughout the sample, and is statistically significant from 1970 through to late 1974, and from 1979 through to late 1981. The negative coefficient on money growth is consistent with Friedman [1996] and Benati and Mumtaz [2007]. These estimates contribute to the literature by for-

malizing the changes in FOMC's objectives using meeting level data, since the latter uses historical data on M2 to estimate their policy rule, while the former does not find the coefficient on money growth to be statistically significant. My findings from 1979 through to 1982 are consistent with Friedman et al. [1996], who find a statistically significant negative weight on M1 growth during this period. From late 1981, the error bands include zero, suggesting that the FOMC stopped pursuing money growth objectives around this period, and supporting the results presented by Meulendyke [1998]. In general, my results are consistent with the observation that the FOMC paid more attention to money growth during the early 1970s, as suggested in Burns [1979] and Sims and Zha [2006] and during Volcker's deflation, as suggested in Friedman et al. [1996].

The coefficient on inflation gradually drifts down from the start of the sample until the early 1980s, with the sharpest fall occurring between 1973 and 1974, and in general always stays below the coefficient estimated by Coibion and Gorodnichenko [2011]. My estimates suggest that the Taylor principle was weakly satisfied during this period, though standard errors include values of the coefficient marginally lower than one. In the second half of 1980s there is a sharp upward drift in the response to inflation, as it rises and remains there for the rest of the sample. The weight on output gap is closer to the estimates suggested in Bernanke and Mishkin [1992] and Orphanides [2002], and rises continuously from 1970 through to 1977, falling gradually during Volcker's deflation. Similar to Kim and Nelson [2006], interest rates are estimated to be volatile for the sample from 1970 through to 1981, but resemble the estimates presented in Coibion and Gorodnichenko [2011] for the remainder of the sample. In general, my results are very different from the policy coefficients estimated in Orphanides [2002], and point to a large variation in the policy parameters during the 1970s and 1980s.

A number of factors could explain the behaviour of the FOMC during this period. First, under this type of framework, the FOMC generally set a monetary aggregate objective, and allowed the Federal funds rate to move up or down if

money was exceeding or falling short of its objective (Meulendyke [1988]). Unexpected changes in the economy, such as aggregate demand shocks, would cause the Federal funds rate to hit the top of its target band, inducing the systems operation manager (SOMA) to conduct open market operations (OMOs). This would cause bank reserves to rise and increase the monetary base, causing money supply to rise. This is exactly what occurred from June 1972 to June 1973 when the economy boomed unexpectedly, and the opposite occurred at the end of June 1974 when the economy contracted, as observed in Mishkin [2007b]. Overall, this meant that instead of raising interest rates when monetary aggregates were outside the target range, interest rates were lowered to keep them in the range, and broad money was allowed to rise over and above the mandated objectives. In the 117 meetings between 1970 through to 1987, targets for M1 growth and the Federal funds rate were moved in the opposite direction more than 80% of the time. The FOMC never seemed to be in control of its money growth objectives, and they were frequently missed (Mishkin [2007b]), and never reversed (Kane [1974], Meulendyke [1988], Larkin et al. [1988] and Mishkin [2007b]). The stop-go nature of monetary policy is epitomized by the volatility of interest rates, and the lack of interest rate smoothing during this period. Since the FOMC was aggressively pursuing its output objectives, money growth objectives would be revised upwards, causing inflation to rise (the go phase). When the FOMC attempted to reverse its decision, it either faced violent opposition from its committee members[16] who bowed to pressure from the Congress, or inflation expectations became embedded so that a large interest rate hike was required but never took place. As soon as

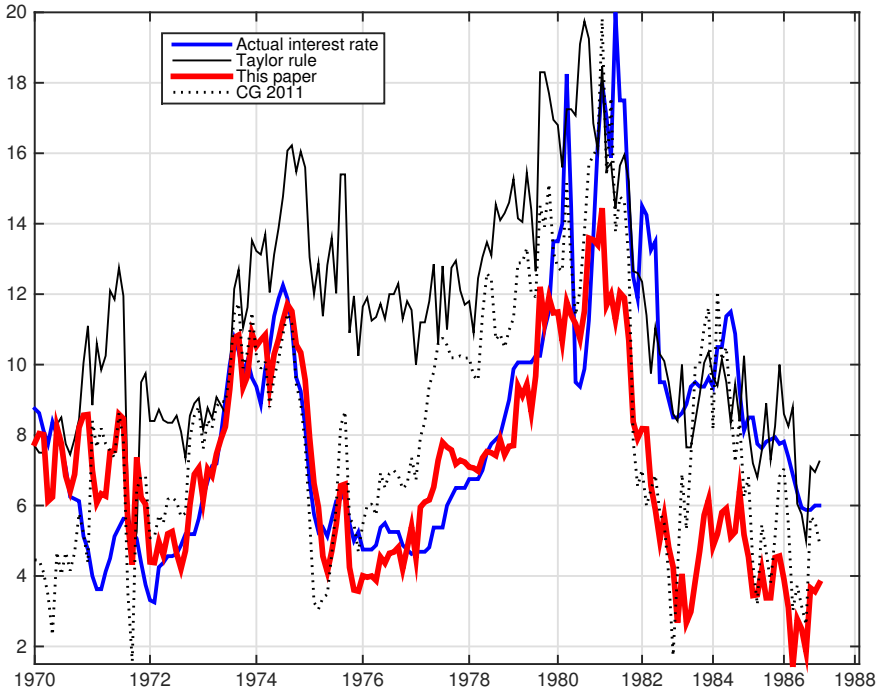
[16]Evidence in support of monetary easing is found in many of the statements by other members. For example, Mr. MacLaury argues against policy tightening and says that the 'directors of the Minneapolis Reserve Bank do not believe that discount rate action would be appropriate at this time, but they do feel that - to use the words of Chairman Burns - a modest and cautious easing of monetary policy would be desirable' (Minutes, 12/18/73, p. 81). At a later time, Mr. MacLaury warned of the political consequences of failing to act against the coming economic slowdown (Minutes, 11/19/73, p. 18). During 1974, the FOMCs gradualist monetary policy (Minutes, 01/21/74, page 20) combined with uncertainty about the source of slack in the economy (Minutes, 6/18/74, p. 68), meant minor changes in beliefs towards the response to inflation, which continue to drift down, and little change in response to monetary aggregates, which falls consistently until about August 1974 before starting to rise.

signs of a recession started building this small period of active policy was reversed in favour of passive policy (the stop phase) as documented by Goodfriend [2005].

Next, I compare the interest rate implied by the baseline estimates of the reaction function that contain a money growth objective, with the estimated coefficients provided by the specifications of the policy rule forwarded Taylor [1993], Coibion and Gorodnichenko [2011], and with actual interest rates set by the FOMC. I derive a series for the interest rates based on the estimated time-varying policy coefficients for each specification of the policy rule. This allows me to evaluate the estimates that best explain the movement in interest rates during the 1970s and 1980s. My estimates suggest that throughout the pre-Volcker period, and during the early 1980s, interest rates implied by the policy coefficients estimated with money growth objectives tracks the behaviour of interest rates better than any of the alternative monetary policy rules. This exercise strongly suggests that a policy rule that takes into consideration M1 growth in the setting of monetary policy during the 1970s better explains actual interest rates observed during this period. The interest rates based on the coefficients estimated using the specification presented by Coibion and Gorodnichenko [2011] also fit the actual interest better than the specification presented in Taylor [1993], but worse than the interest rates implied by a specification that includes money growth. This is primarily because the coefficients introduced in Taylor [1993] imply an interest rate that is higher than actual interest rate during the 1970s. However, this specification tracks the actual interest rates remarkably well for the second half of the data, from 1980 through to 1987. This raises the possibility of a gradual switch in objectives during the early 1980s, since the interest rate implied by the policy rule with money growth starts to drift lower than actual interest rates from this period to the end of the sample. In general, my findings strongly suggest that the baseline policy rule estimated in this chapter explains interest rates better than any of the alternative policy rules during the Great Inflation. Figure 1.5 presents the interest rates implied by each of these specifications compared with actual

interest rates from 1970 through to 1987.

Figure 1.5: Interest Rates Based on Estimated Policy Coefficients



This graph compares the fit of the policy rule by comparing implied estimates of the interest rate with the actual interest rate. The solid blue line is the actual interest rate during this time period. The solid red line is the implied interest rate with the policy rule parameterized with the baseline rule with money growth. The solid black line is based on the estimates of the interest rate under a Taylor rule, and the dotted black line is the implied estimates of the interest rate under estimates of the Coibion and Gorodnichenko [2011] policy rule.

Overall, the estimated coefficients of nominal money growth as an objective of policy suggest a rich pattern in the evolution of monetary policy for the period 1970 through to 1987. The changes in the policy parameters are distinctive across regimes, especially the weight on money growth, which is statistically significant in two independent regimes. In this sense, the response on money growth fluctuated within the subsample, suggesting a regime-dependent type of monetary policy. The FOMC under Chairman Burns reveals an insufficient response

to money growth, providing a novel interpretation of the policy mistakes during the Great Inflation. An additional important contribution of this section is that a monetary policy rule that includes money growth as an objective of policy better fits movements in the interest rate during the Great Inflation. Similar to most of the previous literature (see, for example, Boivin [2005]), the largest changes in the parameters seemed to have occurred during the period 1980 through to 1982.

Estimating the Money Demand Function

Since indeterminacy in this framework is driven by the policy parameters and the relationship between nominal money and inflation, a plausible parameterization of the money demand curve is crucial for pinning down the determinacy regions. Stock and Watson [1993] estimate this type of generalized money demand curve, which explicitly aims to capture the relationship between nominal money and inflation. However, since their focus is primarily on the long run money demand relationship, they ignore any short-term deviations from longer-run estimates. In this context, I estimate a generalized version of the money demand curve, focusing on the following specification of the money demand equation:[17]

$$m_t^n = c_0 + \beta_0 p_t + \beta_1 y_t + \beta_2 i_t + \tau_t \tag{1.21}$$

Following Ireland [2009] and Stock and Watson [1993], I use quarterly data on nominal money, M1,[18] real net national product, the six-month commercial paper rate and the GDP price deflator for the estimation. I use the dynamic OLS (DOLS) techniques developed in Stock and Watson [1993] to estimate this specification. This method estimates a robust single equation approach, which corrects for regressor endogeneity by the inclusion of leads and lags of first differences of

[17] Alternately, I could estimate the log-differenced equation using the treatment introduced in Mehra [1991].

[18] The difference in the results across literature could be driven by the development of electronic payments which may suggest that M1 might not be the most appropriate monetary aggregate to use in the second part of the sample Teles and Uhlig [2010]. However, to compare the behaviour of money demand across samples, I use M1 for all time periods.

the regressors. In addition it has the same asymptotic optimality properties as the Johansen distribution. In order to compare my findings with the existing literature, I also estimate a specification of the money demand when β_1 and β_2 is restricted to zero, and also when β_0 is fixed to one. Table 1.2 summarizes these estimates.

Table 1.2: Estimates of Money Demand Parameters

Sample	Lags & Leads	Point Estimates (Standard Errors) $\eta_\pi(=\beta_0)$	$\eta_y(=\beta_1)$	$\eta_i(=\beta_2)$	c_0
1960 - 2004	–	1.08^{***}	0.35^{***}	-0.02^{***}	-0.95^{**}
		(0.03)	(0.05)	(0.015)	(0.30)
	2	1.08^{***}	0.34^{***}	-0.018^{***}	-0.77
		(0.07)	(0.09)	(0.005)	(0.56)
	3	1.08^{***}	0.34^{***}	-0.018^{***}	-0.72
		(0.08)	(0.11)	(0.005)	(0.70)
	–	1.32^{***}	–	–	1.14^{***}
		(0.009)	–	–	(0.034)
	–	–	0.48^{***}	-0.02^{***}	-1.70^{***}
		–	(0.01)	(0.001)	(0.09)
1960 - 1969	–	1.13^{***}	0.30^{***}	-0.001	-0.75^{***}
		(0.07)	(0.02)	(0.002)	(0.14)
	2	1.82^{***}	0.26^{***}	0.01^{**}	0.43
		(0.09)	(0.03)	(0.004)	(0.27)
	3	0.75^{***}	0.21^{***}	0.01^{***}	0.98^{**}
		(0.09)	(0.03)	(0.004)	(0.30)
	–	1.72^{***}	–	–	0.03
		(0.00)	–	–	(0.00)
	–	–	0.33^{***}	0.002	-0.63^{***}
		–	(0.013)	(0.0016)	(0.10)
1970 - 1979	–	0.58^{***}	0.70^{***}	0.00	-2.4^{***}
		(0.02)	(0.06)	(0.001)	(0.42)
	2	0.50^{***}	0.82^{***}	-0.00	$-3.16**$
		(0.05)	(0.13)	(0.002)	(0.92)
	3	0.46^{***}	0.90^{***}	0.00	$-3.69*$
		(0.08)	(0.20)	(0.002)	(1.46)
	–	0.93^{***}	–	–	2.45^{***}
		(0.00)	–	–	(0.00)
	–	–	-0.085^{*}	0.002	2.93^{***}
		–	(0.03)	(0.002)	(0.31)
1982 - 2004	–	2.91^{***}	-1.00^{***}	-0.015^{**}	3.55^{***}
		(0.30)	(0.20)	(0.004)	(0.71)
	2	2.84^{***}	-1.1^{***}	-0.010^{*}	4.86^{***}
		(0.27)	(0.18)	(0.004)	(0.58)
	3	2.81^{***}	-1.11^{***}	-0.010^{*}	5.22^{***}
		(0.27)	(0.18)	(0.004)	(0.59)
	–	1.85^{***}	–	–	-1.08^{***}
		(0.05)	–	–	(0.21)
	–	–	0.33^{***}	-0.03^{***}	-0.30
		–	(0.05)	(0.004)	(0.52)

The table presents estimates of the generalized money demand curve. Each row presents the results from dynamic OLS, which includes the treatment introduced by Stock and Watson [1993], with the first row using zero lags. I use Newey-West standard errors. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ denote significance levels.

For the complete sample, there is sufficient evidence of a stable relationship between nominal money and inflation, though this relationship changes across periods, as also observed in Sargent and Surico [2011]. There is convincing evi-

dence of a unitary relationship between nominal money and inflation from 1960 through to 1979, which weakens during the 1970s and becomes relatively stronger from 1982 through to 2004. The relationship between nominal money and interest rates also changes over time. There is little evidence of a liquidity effect from 1960 through to 1979, and this relationship almost vanishes during the period 1970 through to 1979. From 1960 through to 1969, there is a positive contemporaneous relationship between money growth and interest rate growth across all estimates, and significant evidence of the well known liquidity puzzle (Gordon and Leeper [1994]). From 1982 through to 2004 there is evidence of the liquidity effect, since the coefficient on interest rates is negative and significant as well as similar to the estimates presented in Ball [1998] and Ireland [2009].

These estimates suggest that there is significant variation in the behaviour of money demand, as compared to longer run estimates presented in Lucas [1980], Ball [1998], Ireland [2009] and Stock and Watson [1993]. Evidence from subsamples suggests that a time-varying money demand curve better elucidates the behaviour during each decade, which supports the main hypothesis presented in Cogley [1993]. Moreover, similar to Sargent and Surico [2011], the behaviour of money demand seems to have changed after 1982, suggesting a strong liquidity effect and a strong relationship between nominal money and inflation.

1.3.2 Determinacy Under Time-Varying Objectives

To assess the likelihood of determinacy during the Great Inflation, I feed the estimated policy and money demand parameters into the parameterized model introduced in section 1.2. I rely on numerical solutions, which allow me to compute the likelihood of determinacy based on the complete span of standard errors of the policy parameters. From a distribution of the estimated parameters, 10,000 draws are computed, and the fraction of draws that yield a determinate rational expectation equilibrium is calculated.[19] To identify the contribution of the two channels

[19] A detailed discussion of this methodology is contained in Coibion and Gorodnichenko [2011] and will not be repeated here.

that affect determinacy in the model, I also present determinacy regions under multiple specifications of the reaction function and the money demand equation.

Figure 6 summarizes the determinacy periods computed using the estimated policy parameters, under the baseline parameterization of the model. My estimates suggest that the likelihood of determinacy was below 50% from July 1970 through to January 1976, and from March 1978 through to October 1982. The high likelihood of determinacy during the first few months of the 1970s suggests that the policy pursued by the FOMC during this period was contractionary. This is similar to the results suggested by Boivin [2005] and Coibion and Gorodnichenko [2011]. However, unlike their paper, my framework suggests that the gradual influence of money growth objectives from the mid-1970s resulted in equilibrium indeterminacy, and once this policy was abandoned around late 1974 the economy drifted back to a determinate equilibrium. From 1975 through to 1978, the economy is estimated to be (weakly) determinate. Furthermore, the change in policy procedures in favour of money growth targeting towards the end of the 1970s shifted the economy back into the indeterminacy region. Finally, the terminal indeterminacy dates in 1982 point to a change in monetary policy objectives, as money growth becomes statistically insignificant in the policy rule. Therefore, the change in policy procedures under Chairman Volcker results in a shift from indeterminacy to determinacy in my baseline characterization of the determinacy regions.

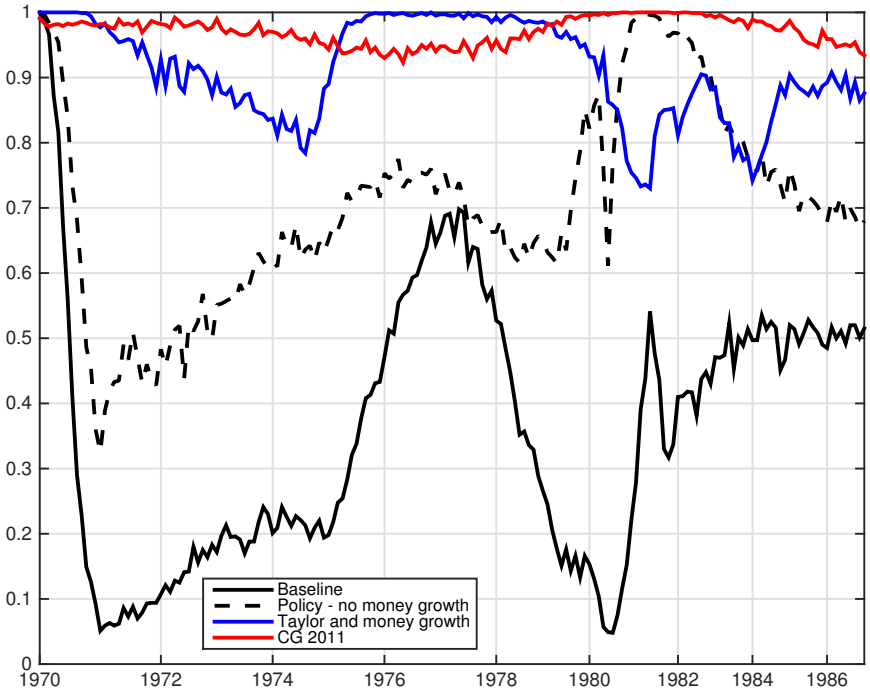
To isolate the contribution of the response to inflation on price level determinacy during this period, I set the weight on money growth equal to zero, and use the estimated policy rule to compute the likelihood of determinacy. As expected, the likelihood of indeterminacy shrinks to a region representing only the time period from October 1970 through to March 1972. This is because conditional on the estimated response towards inflation, monetary policy could have been characterized as weakly active and price level disequilibrium would have only

occurred when the Taylor principle was not satisfied.[20] In this setting, the weak response to money growth mitigated the relatively strong response to inflation and played an important role in triggering and sustaining price level indeterminacy.

I also compare the contribution of a high parameterization of the response to inflation for the likelihood of determinacy, while at the same time use the estimated response to money growth. Under this scenario, the likelihood of the U.S. economy being indeterminate never falls below 80% for the entire sample. This result is in line with the determinacy conditions derived in the first half of the chapter, as the estimated weak response to money growth could have been mitigated had the response to inflation been stronger, over and above the Taylor principle. Therefore, under the baseline parameterization, the U.S. economy would be determinate had the Fed's reaction function not included a money growth objective conditional on the estimated response to inflation, or it had responded sufficiently strongly to inflation, conditional on the estimated response to money growth.

[20]Potentially one can even ignore this period, since it has been argued that a unique equilibrium survives if the Taylor rule is sufficiently active when the economy is in the active policy regime or if the expected length of time the economy will be in the non-active policy regime is sufficiently small (Davig and Leeper [2005]).

Figure 1.6: Baseline Determinacy Rates



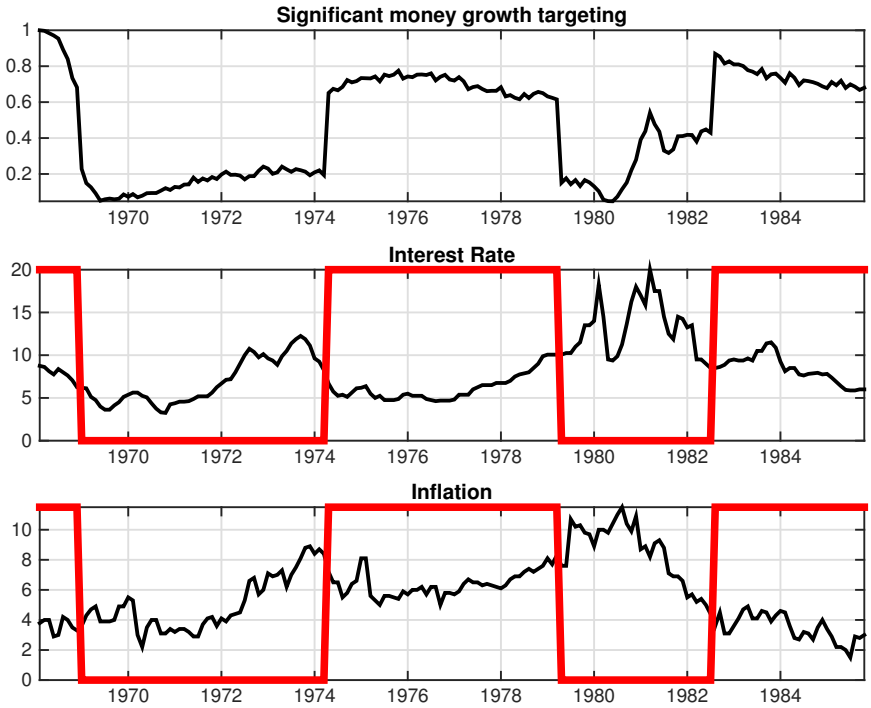
This figure plots the likelihood of determinacy under different policy rules based on the parameterized demand curve. The solid black line represents determinacy under the baseline policy parameters with money growth objectives. The dotted black line presents determinacy under the estimated policy rule, with the coefficient on money growth set to zero. The solid blue line presents determinacy rates with a high parameterization of the coefficient on inflation conditional on the estimated policy rule for output gap and money growth. The solid red line presents determinacy conditions under this model with the estimates of Coibion and Gorodnichenko [2011].

Since the estimated policy coefficients suggest that the monetary authority may have switched its policy objectives multiple times during the Great Inflation, I highlight the effect of this type of policy regime on the likelihood of determinacy. In this setting, I compute the determinacy rates when the coefficient on money growth is significant at 5% in the policy rule. For the periods when the coefficient on money growth enters the policy rule with less than 5% statistical significance, I

assume that the monetary authority has switched to a Taylor type specification.[21] Based on this regime specific objective policy rule, I calculate the corresponding determinacy rates. The likelihood rates suggest results similar to the baseline case, and indeterminacy seems to be prevalent in regimes where money growth objectives significantly influence the setting of interest rates. This exercise reinforces the key point of this chapter, as the sufficiently weak response to money growth had a primary role in rendering policy passive, despite a sufficiently strong response to inflation.

[21]This may also loosely imply that during the periods when money growth was not significant at 5%, the FOMC assigned a weight of zero to money growth objectives. One could potentially repeat this exercise for money growth significant at 10% in the policy rule. However, beyond the money growth being statistically significant at 5% in the policy rule, the coefficient on money growth is only significant at 10% for a few periods. Therefore, I use the estimates when it is significant at 5%.

Figure 1.7: Determinacy Rates under Regime Specific Policy Rule



This figure plots the likelihood of determinacy under the regime switching type policy rule. The top panel presents the likelihood of determinacy, considering only the case when monetary aggregates are statistically significant at 5% in the policy rule. The second and third panel compares this likelihood with interest rates and inflation during this period.

Lastly, in order to isolate the contribution of the behaviour of money demand to price equilibrium determinacy, I replace the parameterized money demand parameters in the previous setting with the estimated money demand parameters. I use estimates of the money demand for the 1970 through to 1979 period.[22] Since the relationship between nominal money and inflation is marginally weaker in the estimated money demand relationship, the indeterminacy region shrinks marginally, and suggests an indeterminate equilibrium from September 1970 through to July 1975, and from May 1978 through to October 1980. This result prompts a number of interesting conclusions related to the indeterminacy

[22]Specifically, I use $\eta_\pi = 0.58$, $\eta_y = 0.70$ and $\eta_i = 0.70$.

periods during the Great Inflation. First, my estimates strongly suggest that indeterminacy under a money growth objective was primarily driven by the choice of monetary policy, compared to the minor role played by the relationship between nominal money and inflation. Second, the U.S. economy is estimated to have shifted to a determinate equilibrium towards the end of 1980. This period corresponds with the observation made in Boivin [2005] as most of the changes in monetary policy seems to have occurred during the 1980s, and not in 1979, as is often assumed. These results are summarized in table 1.3.

Table 1.3: Indeterminacy Time Periods

Policy		
Baseline	July 1970 - January 1976	March 1978 - October 1982
Baseline at 5% significance	September 1970 - December 1974	April 1979 - December 1982
$\psi_{\Delta m} = 0$	October 1970 - March 1972	
Money demand		
Estimated 70 - 79	September 1970 - July 1975	May 1978 - October 1980
$\eta_\pi = 1$	August 1970 - January 1976	March 1978 - August 1983

This table presents the time periods during which the estimated policy rule yielded an indeterminate price equilibrium. The first column presents the role of policy parameters based on the baseline money demand function, while the second panel focuses on money demand parameters conditional on estimates of the policy parameters. For the money demand equation, I use the parameters suggested by the generalized money demand estimates.

The results with time-varying parameters confirm the key role played by shifts in the objectives of monetary policy in accounting for the apparent transition from determinacy to indeterminacy in the early 1970s, and then back to determinacy towards the end of the Volcker deflation, as also suggested by Clarida et al. [2000] and Coibion and Gorodnichenko [2011]. During this period, had the FOMC followed the type of regime espoused by Taylor [1993] or Coibion and Gorodnichenko [2011], the probability of determinacy would be approximately 99%. In this context, my estimates suggest that a gradual abandoning of money growth objectives in favour of a Taylor type specification during the 1980s may

have switched monetary policy from passive to active, and assisted in yielding a determinate price equilibrium. Contrary to the findings presented in Orphanides [2002], these results point to a large variation in the policy parameters that led to an indeterminate equilibrium during the 1970s and 1980s. My estimates also suggest that the idea that U.S. economic history can be divided into pre- and post- Volcker turns out to be misleading, since there are multiple regimes where monetary policy is estimated to be passive, resulting in price level indeterminacy (see, for example, Sims and Zha [2006], and Bianchi [2012]). Broadly speaking, pursuing a money growth objective may have activated money demand instability (Sargent and Surico [2011]), which may affect the likelihood of indeterminacy as implied by my theoretical conditions, but empirical estimates suggest that this effect is not sufficient to have a large effect on the likelihood of indeterminacy, which was predominantly affected by the nature of policy pursued by the monetary authority.

1.3.3 Volatility, Welfare and Counterfactuals

I now analyze the consequences for volatility and welfare that are due to the FOMC pursuing money growth objectives during the Great Inflation. This exercise is motivated by empirical evidence from Perez-Quiros and McConnell [2000], who identify a large decline in the volatility of aggregate economic activity, employment and inflation since the early 1980s. Previous studies offer several potential explanations for this "Great Moderation". Some studies point to evidence that output volatility fell more than sales volatility and highlight the potential role of better inventory control methods (see, for example, Kahn et al. [2002]). Another line of research stresses "good luck" in the form of smaller exogenous shocks (see, for example, Stock and Watson [2002]). The last explanation is based on “better" monetary policy, which examines the contribution of changes in monetary policy to the reduction in macroeconomic volatility (see, for example, Clarida et al.

[2000]).[23]

To assess the contribution of the role of the monetary policy reaction function on economic volatility, I compare the volatility generated by the estimated policy reaction function with volatility generated under alternative policy rules. In particular, I compare the estimated policy rule with parameters of the specification presented in Coibion and Gorodnichenko [2011], a standard Taylor rule, and a constant money growth rule. To differentiate the macroeconomic consequences of the actual policy during this period with macroeconomic volatility under (hypothetical) 'better' policy, I perform policy counterfactuals by combining the coefficients of the baseline Taylor rule with a positive coefficient on money growth. For each type of policy rule, welfare loss to steady state consumption is computed using the welfare loss function presented in Gali [2009]. I use point estimates for the reaction function, which is calculated by averaging the response in the policy rule during the 1970 to 1979 time period. Table 1.4 summarizes the results.

[23] Summers [2005] perform a cross country analysis which confirms the role of monetary policy in reducing the macroeconomic volatility across countries.

Table 1.4: Estimates of Volatility and Welfare

	1970 - 1979				Policy counterfactuals		
	M.T	Taylor	CG	$\Delta m_t = 0$	M.T - I	M.T - II	M.T - III
ψ_π	1.35	1.5	1.59	-	-	-	1.5
$\psi_{\Delta m}$	-0.18	-	-	-	1.5	1.5	0.5
ψ_{gy}	-	-	0.39	-	-	-	
ψ_x	0.18	0.125	0.41	-	-	0.125	0.125
ρ_1	0.67	-	0.75	-	-	-	-
ρ_2	-0.22	-	-0.27	-	-	-	-
$\sigma(\pi)$	3.03	1.76	2.09	2.5	3.74	3.10	1.37
$\sigma(x)$	1.39	0.92	1.01	1.19	1.74	1.48	0.98
$\sigma(gy)$	1.34	0.78	0.78	0.73	1.02	0.92	0.70
Welfare Loss	1.62	0.55	0.77	1.10	2.47	1.70	0.33

The table presents point estimates of the volatility in inflation, output gap, output growth, interest rates, money growth, and the corresponding welfare losses under each type of monetary policy rule. Here M.T denotes monetary policy under the baseline monetary aggregate targeting rule and CG refers to the rule espoused by Coibion and Gorodnichenko [2011]. The last three columns present policy counterfactuals. Since output gap is quarterly, the response to output gap under M.T and CG is converted to a quarterly rate for this exercise. I use the baseline parameterization for the structural model.

Conditional on the baseline parameterization of the model, the actual policy adopted by the FOMC is estimated to have contributed significantly to macroeconomic volatility. Under the baseline policy rule, a negative weight on money growth mitigates the response of interest rates to inflation.[24] Based on this policy, the aggregate response of the central bank to a structural shock is lower, compared to the rise in interest rates suggested by a Taylor type policy rule.[25] In this context, compared to a baseline Taylor type policy rule, inflation is estimated to be 42% more volatile, the output gap is 33% more volatile, and output growth is 41% more volatile. Therefore, this policy results in welfare losses of more than

[24] As shown in the appendix, one can replace money growth in the policy rule with the generalized money demand curve. In that case the coefficient on money growth affects the response to inflation, output gap and lagged interest rates.

[25] Under the Taylor rule the monetary authority would raise interest rates, cause a recession, and keep inflation close to its long run target.

1.07% of steady state consumption compared to a Taylor type specification. A comparison of the actual policy rule with the baseline Coibion and Gorodnichenko [2011] type policy specification suggests 32% higher inflation volatility, 27% more output gap volatility, and 41% higher output growth volatility, resulting in welfare losses of more than 0.85% of steady state consumption. This is because responding to the output growth rate effectively makes the policy reaction function history dependent. Pursuing only money growth objectives makes the policy too accommodating and yields a welfare outcome similiar to a constant money growth rule. Finally, comparing the hypothetical 'good policy' in the form of a Taylor rule plus a positive weight on money growth results in an equilibrium outcome that suggests welfare gains of 0.22% of steady state consumption over and above a Taylor rule. Under this type of rule, the aggregate response of the monetary authority to changes in inflation is greater, and the policy induces interest rate inertia and history dependence.

To capture the contribution of monetary growth objectives alone to macroeconomic volatility, I parameterize the monetary policy rule with the parameters presented by Coibion and Gorodnichenko [2011], but include the estimates of the coefficients on money growth. This policy rule still generates 13% additional output growth volatility, 11% additional inflation volatility, and 30% additional output gap volatility. Therefore, a weak response to money growth despite an otherwise aggressive monetary policy rule still contributes to macroeconomic volatility. Table 1.5 summarizes these results.

Table 1.5: Estimates of Counterfactual Volatility

	$\sigma(\pi)$	$\sigma(x)$	$\sigma(gy)$
Baseline	3.03	1.39	1.34
CG	2.09	1.01	0.78
CG with M.T	2.38	1.15	1.13
Excess	12%	12%	30%

The table presents counterfactual estimates of the policy rule. The first row presents baseline estimates of volatility, the second row ('CG') presents estimates of volatility from the Coibion and Gorodnichenko [2011] type rule, while the third row ('CG with M.T') presents estimates of volatility given the parameters under Coibion and Gorodnichenko [2011] rule with money growth from the actual estimated sample. The last column presents the excess volatility contributed by pursuing a money growth objective.

My results strongly suggest that a sizeable portion of the reduction in macroeconomic volatility during the 1970s could be attributed to loose monetary policy, and support the evidence proposed by Roberts [2006], Leduc and Sill [2007] and Taylor [2013]. Since the negative weight on money growth is incompatible with the response of the monetary authority to inflation, the model predicts large welfare losses under the parameterized model. These results provide compelling welfare based reasons for the FOMC abandoning its attempt to use money growth as an objective of policy, and focusing on following a Taylor type policy rule. This also supports my empirical evidence, as the interest rates based on the Taylor rule are shown to better match actual interest rates from the 1980s. Last, policy counterfactuals suggest that a sufficiently strong response to money growth yields welfare outcomes superior to any other policy rule, since it induces interest rate inertia and history dependence, which are, as suggested by Woodford [2011], hallmarks of good policy.

1.4 International Evidence of Money Growth Targeting

Based on the parameterized structure of the economy and the structural shocks, a weak response to money growth objectives is estimated to have contributed to macroeconomic volatility in the U.S. An important outcome from analyzing the U.S. case suggests that there may be positive welfare gains to be made from switching to a speed-limit policy, or to a standard Taylor type specification. Alternatively, pursuing money growth objectives sincerely, by responding sufficiently strongly to growth in money, could result in positive welfare gains. In this context, it may be reasonable to examine the robustness of the relationship between pursuing monetary growth objectives and macroeconomic volatility across countries. In general, I want to compare macroeconomic volatility for countries that focus on pursuing inflation objectives with countries that pursue money growth objectives equivalent to the U.S. Countries that pursue both inflation and money growth objectives are categorized according to statistical significance. Therefore, if the estimates suggest that the weight on money growth is significant, and the coefficient on inflation is also significant, the country is categorized as a 'money growth targeter'. A country that only targets inflation is categorized as an 'inflation targeter'.

In this spirit, I estimate the baseline constant parameter policy rule presented in this chapter for all available countries from 1970 through to 2006 using the World Bank database. Countries that have many missing observations or do not pursue any of these types of policies are excluded from the sample. The final dataset consists of thirty-four countries, for which I have data on inflation, output growth, money supply (M1), and interest rates. Based on the estimates of the policy rule, I split the sample into countries that pursued money growth objectives equivalent to the U.S. case, and countries that pursued inflation objectives. I use least squares to estimate this policy rule. I then calculate inflation and output

volatility for both sets of countries, and take the average for that category.[26] Table 1.6 summarizes my results.

Table 1.6: Cross-country Estimates of the Reaction Function

Money growth targeters			Inflation targeters		
Country	Output volatility	Inflation volatility	Country	Output volatility	Inflation volatility
Australia	1.68	4.18	Bangladesh	1.42	7.03
Barbados	3.74	5.28	Belize	4.18	3.48
Benin	4.2	5.92	Canada	1.99	3.56
Burkina Faso	3.8	6.66	China	2.89	5.2
El Salvador	2.31	3.06	Denmark	1.77	2.97
Honduras	2.65	8.96	Egypt	2.87	6.72
Mali	6.4	7.16	Finland	2.80	3.49
Norway	1.64	4.42	Hungary	4.16	9.7
Singapore	3.73	3.16	India	2.90	3.20
South Africa	2.33	4.54	Japan	2.52	5.56
Sri Lanka	1.82	4.89	Kenya	4.44	8.27
Thailand	4.32	3.16	Korea	3.89	5.03
Zimbabwe	3.57	9.9	Lesotho	2.43	8.42
Italy	1.42	5.67	Morocco	4.60	4.17
			Paraguay	2.66	8.17
			Philippines	3.52	9.11
			Sweden	1.85	3.91
			Switzerland	1.57	1.92
			United Kingdom	1.57	5.83
			United States	1.94	2.48
Average	3.52	5.50		2.86	5.40

The table presents macroeconomic volatility in countries which target money and countries which target only inflation. The data covers the period 1970 through to 2006. The volatility of each variable is calculated by taking the standard deviation of the sample.

My estimates provide a novel insight into monetary policy regimes across

[26]For robustness I also estimate this rule for all countries from 1960 through to 2006, 1980 through to 2006 and 1990 through to 2006 but my main results do not change.

countries. First, I find that out of the thirty-four countries in the data sample, fourteen countries pursued money growth objectives, and twenty countries pursued inflation objectives from 1970 through to 2006. Comparing the macroeconomic volatility of these two samples suggests that countries that focused on achieving their money growth objectives also, on average, experienced more inflation and output volatility. This is consistent with the evidence discussed in this chapter, as pursuing money growth objectives is estimated to contribute significantly to macroeconomic volatility. Moreover, some of these countries are also estimated to place a statistically significant negative weight on money, suggesting that these countries may be faced with price indeterminacy issues similar to those experienced by the U.S. economy during the 1970s. As suggested by the model, there should be positive welfare gains from switching to a Taylor type policy in countries that continue to target money growth.

1.5 Conclusion

In this chapter I study the role of money growth as an objective of monetary policy by examining its contribution to price level determinacy. Specifically, I apply this framework to analyze the rise in macroeconomic instability experienced by the U.S economy during the 1960s and 1970s. In my framework, policy mistakes in the form of a weak response to money growth triggered indeterminacy, despite a relatively strong response to inflation. Therefore, my results suggest the reduction in macroeconomic instability during the 1980s could be largely attributed to the FOMC relinquishing money growth objectives. These findings present a novel channel that provides additional support for the well-known view that changes in monetary policy may have played an important role during the Great Inflation.

In order to examine the effect on price equilibrium when the monetary policy rule includes money growth as an objective, I derive novel determinacy conditions that depend on monetary policy coefficients, and on the behaviour of

the money demand curve. I show that instability in the traditional money demand relationships or a weak response to money growth triggers indeterminacy, irrespective of the Taylor principle being satisfied. In this case, it may be desirable for the central bank to switch to an inflation-targeting regime in order to guarantee determinacy. In general, these results contribute to the theoretical literature which has focused only on the response towards inflation as a pre-requisite of active policy (see for example Friedman [2000], Woodford [2001] and Carlstrom and Fuerst [2003]). Using extended FOMC data on monetary growth M1, I provide novel empirical evidence of changes in the objectives of monetary policy, as money growth is shown to have significantly influenced the setting of interest rates during the first half of the 1970s, and during Volcker's deflation. These empirical results extend the evidence provided in Burns [1979], and Sims and Zha [2006], and contribute to the findings of Benati and Mumtaz [2007], Friedman [1996], and Clarida et al. [1998]. My central findings suggest that the US economy experienced indeterminacy from 1970 through to 1976, and then from 1978 through to October 1980, before finally moving to a determinate equilibrium, supporting the implications put forward by Clarida et al. [2000], and Coibion and Gorodnichenko [2011]. However, in my framework, a weak response to money growth mitigates the relatively strong response to inflation, rendering policy passive. I show that the choice of monetary policy seems to be the primary factor driving price level indeterminacy, with the estimated money demand instability playing a minor role in the empirical characterization of determinacy. Generally, characterizing monetary policy in pre-and-post-Volcker terms seems to be misleading, since multiple policy regimes appear to have been in place during the 1970s. This supports the hypothesis suggested by Sims and Zha [2006] and Bianchi [2012]. My counterfactual simulations suggest that substantial welfare gains could be realized if the monetary authority switches from the estimated policy rule to a Taylor type specification. This formalizes welfare-based evidence of the gradual departure of money growth from monetary policy deliberations. I confirm the correlation between countries

that pursue money growth objectives similar to the U.S. and high macroeconomic volatility, using cross-country data.

Even though the monetarist experiment was abandoned during the 1980s, my results may have relevant policy implications. The current state of the economy suggests an unprecedented growth in liquidity. In this environment, central banks may be tempted to (re)introduce money supply as an objective of policy, or as a possible indicator of long run inflation. Due to the possibility of inducing sunspot equilibrium, and therefore causing macroeconomic instability, my results call for caution in using this type of policy. Although instability in the money demand function plays a minor role in pinning down indeterminacy in my framework, further research is needed to fully understand the drivers of the parameters of the demand curve. Future work may include treating these drivers as endogenous in an empirical and theoretical model.

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Chapter 2

What are Monetary Policy Shocks?

2.1 Introduction

In a standard business cycle model, deviations in the Federal funds rate from a Taylor type monetary policy rule are a significant source of business cycle fluctuations (see, for example, Christiano et al. [2005], Gali [2009], Smets and Wouters [2007] and Justiniano and Primiceri [2008]). Primarily documented as the residual of a standard monetary policy feedback rule, the contribution of these shocks may be overestimated if the monetary policy reaction function is misspecified. In such a framework, what is perceived to be an exogenous change in the interest rate could be due to a change in an endogenous but latent variable in the feedback rule. In this context, the model would wrongly attribute a significant fraction of business cycle fluctuations to exogenous changes in monetary policy, which may actually be due to changes in the endogenous part of the feedback rule. By allowing the inflation target to evolve over time, I examine the impact of this type of misspecification in the feedback rule on the magnitude of exogenous monetary policy shocks.

I answer this question in two parts. To disentangle the variation observed in the interest rate from the variation observed in the inflation target, I extrapolate a series for the inflation target from a standard monetary policy reaction function,

and use it to estimate a large business cycle model of the U.S. as presented in Smets and Wouters [2007]. In the model, the inflation target is included in an otherwise standard reaction function as a stochastic process. I use the results from the estimated model to examine the contribution of the time-varying inflation target on the measurement and the behaviour of exogenous monetary policy shocks by conducting a battery of exercises. The model is also used to study the contribution of the time-varying inflation target on the dynamics of the U.S. economy.

My first set of results suggest that the inflation target rises from 2% in the early 1960s to 7.5% during the 1970s, falling to 1.5% during Volcker's disinflation, and finally stabilizes around 2% during the 1990s. This follows a pattern similar to the model-implied series estimated in Ireland [2005], Milani [2006], and Coibion and Gorodnichenko [2011]. Moreover, a time-varying inflation target is found to be an appropriate misspecification to study the evolution of policy shocks compared to other possible misspecifications in the feedback rule. By considering multiple specifications for the inflation target to estimate the model, I rule out the possibility of the Federal Reserve responding to structural shocks through adjusting the inflation target, rejecting the conclusions presented in Gavin et al. [2014]. Moreover, my baseline findings contribute to the literature examining the role of structural shocks and monetary policy, and rule out the possibility that monetary policy shocks are contaminated with structural shocks.[1] The estimated model with a time-varying inflation target also improves the fit of the Smets and Wouters [2007] model.

My main results show that including a time-varying inflation target leads to a large reduction in the variance of exogenous monetary policy shocks. Comparing exogenous monetary policy generated from a fixed inflation target model with these shocks generated from a time-varying inflation target model suggests that a time varying inflation target can explain up to 47% of the variance attributed

[1] By allowing structural shocks to be correlated to monetary policy shocks in the model does not improve the fit of the model, nor reduced the estimates of the exogenous policy shocks. Overall these exercises allow me to reject this interpretation of the 'opportunistic approach to disinflation' theory (Orphanides and Wilcox [1996]).

to exogenous monetary policy shocks. Estimating a stochastic volatility model with these series confirms this result. Critically, the peak in variance of exogenous monetary policy shocks are highly correlated with the peak in the variance of shocks to the inflation target, strongly suggesting that exogenous changes in the interest rates are correlated with changes in the inflation target. In general, shocks to the time-varying target are largest during the mid 1970s and during the early 1980s, and explain a large fraction of the variation observed in exogenous monetary policy. Therefore, the important policy changes described by Boivin [2005] during this period, and the high volatility of exogenous shocks in post-War U.S identified in Justiniano and Primiceri [2008], may be attributed to changes in the inflation target.[2]

These results contrast sharply with the conclusions based on a model with a fixed inflation target (see, for example, Christiano et al. [2005], Gali [2009] and Smets and Wouters [2007]), and suggest that a fixed inflation target may have overestimated the variance and the contribution of monetary policy shocks to the macroeconomic dynamics. I quantify the role of exogenous shocks in a time-varying target model and compare to the dynamics of these shocks under a fixed inflation target model in the U.S. economy. This framework suggests that traditional exogenous monetary policy shocks have been attributed an excess of 12% volatility in interest rates, 30% volatility in inflation, 24% volatility in output and 27% volatility in labor hours, extending the contribution made by Smets and Wouters [2007] in accounting for the evolution of macroeconomic dynamics in the U.S. In general, these results formalize evidence that the misspecification in the feedback rule may have resulted in overestimating the macroeconomic consequences of pure exogenous changes in the feedback rule.

[2]Accordingly, this approach to remove contamination in monetary policy shocks may depict a closer description of monetary policy shocks, and more in line with the classic approach espoused by Friedman and Schwartz [2008], who explain these shocks to be unusual actions of the FOMC given the state of the economy. Romer and Romer [1989]'s approach - which in their own words is quite limited - defines monetary policy shocks as attempts by the Federal reserve to specifically cause recessions, and cure inflation, and therefore excludes both monetary contractions that are generated by concerns other than inflation and all monetary expansions, and is a subset of Friedman and Schwartz [2008]'s original hypothesis.

Second, I focus on the contribution of the time-varying inflation target on the macroeconomic volatility experienced by the U.S economy during the pre-Volcker period. Since the inflation target is more than twice as volatile in the pre-Volcker period as compared to the post-Volcker period, this increases the volatility of the interest rate rule. My results suggest that approximately 39% of the volatility in inflation may be attributed to the time-varying inflation target,[3] contributing to the findings of Clarida et al. [2000], Summers [2005], Taylor [1999] and Primiceri [2005]. While the quantitative implications of this result are similar to Castelnuovo [2012c], my interpretation suggests that frequent changes in the inflation target constitute a policy mistake, which contributed to the macroeconomic volatility experienced by the U.S. during the Great Inflation. Stabilizing the inflation target close to the 2% range during the post-Volcker period might have helped anchor inflation expectations and contributed to macroeconomic stability. Therefore, the time-varying systematic policy rule considered in this chapter may partially account for the role of monetary policy in the rise and fall in macroeconomic volatility experienced by the U.S. economy.

Lastly, I study the policy implications of a time-varying inflation target by comparing the effects of an exogenous shock to the inflation target with the effect of an exogenous shock to the interest rate. In the model, the monetary authority can either change the interest rate directly for a given inflation target or change the inflation target. Since the response of output, labor hours and inflation to a shock to the inflation target is very different from a shock to the interest rate, each policy implies economic trade-offs, which are tabulated by calculating sacrifice ratios. In lost output terms, it costs 4.5 times more to cause disinflation when using exogenous interest rate changes compared to changing the inflation target. In my framework the change in the inflation target is implemented gradually giving expectations time to adjust to the new target, causing the output effects of the change in inflation to be much smaller. It is due to this gradual

[3]Similar to the results found in Smets and Wouters [2007], changes in monetary policy parameters play a negligible role in explaining the Great Moderation

adjustment of the inflation target that my findings contrast with the literature on unannounced changes in the inflation target. For example, Ball and Reyes [2007] find a larger welfare loss associated with changes in the inflation target. My findings are different from existing literature in which sacrifice ratios are studied based only on exogenous changes in the interest rate (see, for example, Cecchetti and Rich [1999]). In general, my results may contribute to reconciling the variability in the range of the sacrifice ratio tabulated across different studies (see, for example, Fuhrer [1994], Wascher et al. [1999], and Cecchetti and Rich [1999]).

This chapter is closely related to Castelnuovo [2012c], Ireland [2005], Smets and Wouters [2007] and Fuhrer [1994]. Whereas Castelnuovo [2012c] focuses on the contribution of shocks to trend inflation on macroeconomic dynamics, my main focus is the impact of misspecifications in the reaction function on exogenous interest rate shocks. Our findings overlap by studying the behaviour of macroeconomic dynamics of time-varying inflation targets. Even on this issue our interpretations differ, since my framework views changes in the inflation targets as deliberate policy actions of the Fed, as compared to his ad-hoc mechanism which stabilizes trend inflation. This has important policy prescriptions as my results suggests that stabilizing the inflation target contributied to macroeconomic stability, a conclusion that is close to the implications forwarded by Tetlow [2008]. Moreover, I also focus on the policy implications of these policy shocks. This chapter is also different from Ireland [2005], whose primary focus is on the causes and consequences of changes in the inflation target. By extending the contribution to a larger model, I focus on the relationship between changes in the inflation target and the impact on exogenous policy shocks, as well as on macroeconomic dynamics, in light of the extra volatility observed during the Great Moderation. On the policy and sacrifice ratio side, my chapter builds on the findings of Fuhrer [1994], who focuses on the sacrifice ratio entailed in the Great Moderation. The main difference between our findings is that I include a time-varying inflation target shock, and interpret it as a deliberate policy action. In this sense, this type of policy enumerates a different

sacrifice ratio compared to the sacrifice ratio generated by an exogenous shocks to the interest rate. Finally, this chapter rests on the Smets and Wouters [2007] framework but includes a time-varying inflation target, and uses a series for the inflation target obtained outside the model to estimate the full structural model. Therefore, my approach provide the model with extra information in the form of an observable time series for the inflation target.

The chapter is presented in the following order: in section 2.2, I extrapolate an implicit inflation target using a standard monetary policy rule. In section 2.3, I estimate a large business cycle model of the U.S. with a time-varying inflation target, and discuss the results of the estimation. In section 2.4, I show that (a) the volatility observed as exogenous monetary policy shocks may be partially explained by a time-varying target, (b) study the counterfactual effects on the volatility of the U.S. economy during the subsample periods, and the role of inflation target shocks in the Great Moderation and (c) compare the impact of exogenous movements in the interest rates and compare them with exogenous changes in the inflation targets. Section 2.5 concludes, with some suggestions for future research.

2.2 The U.S Inflation Target

Since the Federal Reserve does not explicitly announce its inflation target, I infer it by applying econometric techniques to historical data. I use this series as an observable to estimate a model of the U.S. economy. To estimate this policy rule, I assume that the behaviour of the monetary authority can be captured by a standard feedback rule, as proposed by Taylor [1993] and generalized in Woodford [2011].[4] I parameterize this policy rule across a wide range of policy parameters to extrapolate multiple possible series for the inflation target.[5]

[4] A more complicated process for monetary policy, such as the one considered in Coibion and Gorodnichenko [2011], will allow me to identify a similar series for the inflation target but I use this process for its simplicity.

[5] In this context, assuming a widely accepted, monetary policy rule may be fairly standard, the latter assumption regarding the parameters governing the feedback rule may be controversial. Many authors (see, for example, Boivin and Giannoni [2002], Clarida et al. [2000], Cogley and Sargent [2005], Judd and Rudebusch [1998], and Lubik and Schorfheide [2004]) have argued that

Since I estimate multiple series for the inflation target that encompass multiple calibrations of the policy parameters, I allow the estimated model to predict the parameters on the feedback rule, and identify the series for the inflation target which best fits the other observed series from actual data. Moreover, I do not impose any restrictive structure on the inflation target, as extrapolating the inflation target with assumptions on the structural model at this stage might contaminate the series. This could lead us wrong attribution of the movement in the inflation target to elements that may not even enter the evolution of the inflation target. I apply maximum likelihood techniques to extrapolate the inflation target from the policy rule using the Kalman filter to estimate the following equation:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)[\phi_\pi[\pi_t - \pi_t^T] + \phi_x x_t] \tag{2.1}$$

$$\pi_t^T = n_t + \theta_t \tag{2.2}$$

$$n_t = \rho_\pi n_{t-1} + \epsilon_t^\pi \tag{2.3}$$

$$\theta_t = \phi_1 \theta_{t-1} + \phi_2 \theta_{t-1} + \epsilon^x \tag{2.4}$$

In this equation, r_t is the nominal interest rate set by the monetary authority, π_t is annualized inflation and x_t is the output gap. The parameters ϕ_π and ϕ_y represent the degree of policy preferences of the monetary authority to inflation and output, respectively, while ρ_r captures the persistence of interest rates. I assume that the inflation target, π_t^T, is a function of two unobservable components, and is represented as the sum of the stationary (n_t) and the non-stationary (x_t) processes. This evolution of the inflation target nests the cases considered in Ireland [2005] and Cogley et al. [2008] as special cases, and is therefore modelled as a stochastic process. Notice that estimating this model will determine the persistence of the

US monetary policy was less active against inflationary pressures under the Federal Reserve chairmanship of Arthur Burns than under Paul Volcker and Alan Greenspan. Other studies have found either little evidence of changes in the systematic part of monetary policy (Hanson [2006], Leeper and Zha [2003]) or no evidence of drifts in policy toward a more active behaviour (Sims [1999] and Sims [2001]).

model, which in the literature is typically modelled as a very persistent variance-stationary process as presented in Castelnuovo [2012c]. The series for the inflation target described in equation 2.1 is extrapolated across different parameterizations of ρ_r, ϕ_π and ϕ_x. Kalman filtering using maximum likelihood techniques is applied to decompose n_t and θ_t and estimate the parameters governing the process, where ρ_π is the persistence of the stationary part of the inflation target, ϵ_t^π may reflect discretionary changes in the inflation target, ϕ_1 and ϕ_2 are the coefficients of the first and second lag, respectively, of the non-stationary part and ϵ^x represents shocks to the white noise process. This specification for the unobservable component allows me to separate the inflation trend from the cyclical component, which may be white noise resulting from data revisions, as suggested in Bernanke and Mihov [1998].

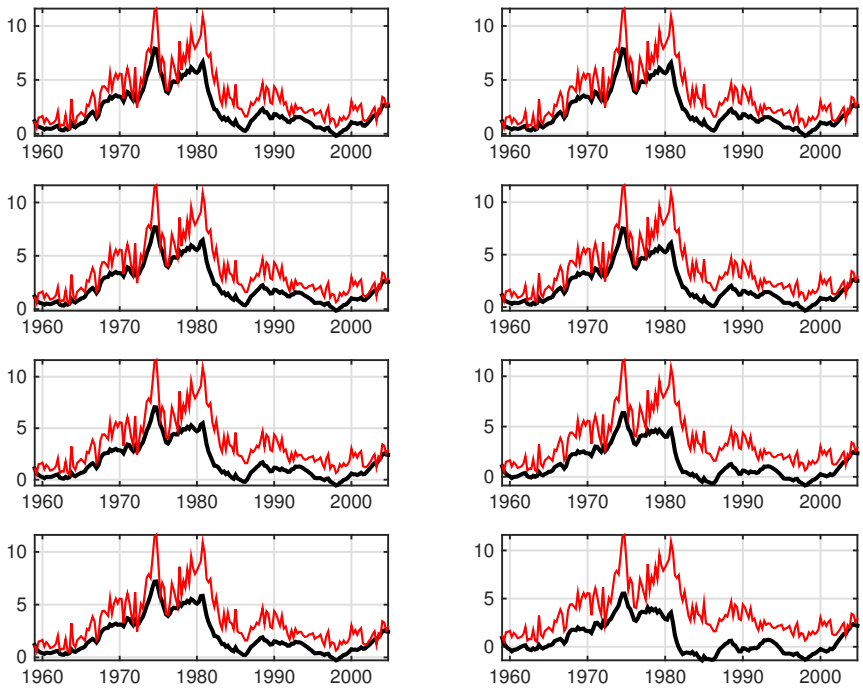
While the natural rate of output and the inflation target cannot be separately identified, I assume that the natural rate is the average of the nominal interest rate over the sample, as also considered by Coibion and Gorodnichenko [2011]. Corresponding data is matched as follows: I use quarterly U.S. data on inflation, the output gap, and the federal funds rate, spanning the period between 1959:I and 2004:IV. The output gap is calculated as the log difference between real GDP and the CBO's Potential GDP estimate, inflation is calculated as the quarterly log difference of the GDP Implicit Price Deflator, and the federal funds rate is used in levels and transformed to yield quarterly rates.[6]

Figure 2.2 plots multiple series for the estimated Federal Reserve's inflation target, as well as annualized inflation during the time period. The time series properties of the evolution of the inflation target are close to the series estimated in Ireland [2005], Milani [2006], and Coibion and Gorodnichenko [2011]. The target rises from below 2% in the early 1960s, but quickly moves upward in the late 1960s and early 1970s to values slightly above 4.5%. The inflation target then reaches a peak of around 7% in the early 1970s, before falling to around 1-1.5%

[6] I also use HP-filtered (Hodrick and Prescott [1997]) output as discussed in Gali [2002] as an estimate of potential GDP to check for robustness, but my main results do not change.

during Volcker's disinflation period. The sharp fall in the inflation target during Volcker's disinflation is close to the findings of Tetlow [2008]. After 1990, the target stabilizes around 1-1.5% (a large decline in the target is observed at the same time as the 1990-1991 recession, a pattern that is consistent with results obtained in Leigh [2008]). Finally, the target rises back to between 1.75 - 2.5% in 2004.

Figure 2.1: The U.S Inflation Target



This figure plots the evolution of the U.S. inflation target. The solid red line represents actual inflation from, while the solid black line represents the extrapolated inflation target. The sample covered is from 1959:I through to 2004:IV.

Table 2.1 tabulates the estimated parameters. My estimates suggest that a high value of the response to inflation, a very low weight on the coefficient on the output gap, and a low weight on interest rate smoothing, as adjudicated by applying the Akaike Information Criterion (AIC), and the Bayesian Information

Criterion (BIC) test on the likelihood of the estimation $l(\theta^{ML})$,[7] best represent the data. The persistence of the inflation target is estimated to be high (0.98) while exogenous movements in the inflation target, captured by standard deviation of ϵ_t^{π}, range between 0.68 and 0.75 percentage points. My estimates of the persistence and exogenous components of the inflation target justify the prior used by Ireland [2005] in his model, though my framework explicitly estimates these parameters. Given the non-stationary assumption of θ_t, the parameters ϕ_1 and ϕ_2 are both low and have opposite signs, and are not significantly, while shocks to the white noise process are around 0.5 percentage points, and are almost as large as the shock to the inflation target.

Table 2.1: Inflation Target, 1959:1 - 2004:75

Model	Fixed			Estimated Parameters					
	ϕ_π	ϕ_x	ρ_r	ρ_π	ϵ_t^{π}	ϕ_1	ϕ_2	ϵ^x	$l(\theta^{ML})$
1	4	0.05	0.1	0.98	0.68	0.04	-0.05	0.52	-311.4
2	4	0.05	0.25	0.98	0.69	0.03	-0.05	0.51	-312
3	3.5	0.05	0.25	0.98	0.7	0.05	-0.05	0.5	-312.4
4	4	0.05	0.4	0.98	0.71	0.05	-0.04	0.5	-313.4
5	3	0.05	0.25	0.98	0.72	0.06	-0.05	0.49	-313.5
6	2.5	0.1	0.1	0.97	0.74	0.09	-0.04	0.48	-314.8
7	3.5	0.05	0.5	0.98	0.76	0.07	-0.05	0.47	-317.8
8	2	0.1	0.05	0.96	0.75	0.12	-0.05	0.5	-319.1

The table presents the values of the parameters governing the process for the inflation target using maximum likelihood techniques across different values of the monetary policy rule. The last column presents results of the log-likelihood of the estimation.

2.3 Model and Estimation

Using these multiple extrapolated series for the inflation target, I estimate a large business cycle model of the U.S. presented by Smets and Wouters [2007], with a stochastic inflation target in the monetary policy feedback rule. In the first step I estimate three versions of the model, using the estimated series for the inflation target. I estimate a model with a fixed inflation target, which forms my benchmark

[7] Given a set of candidate models for the data, the preferred model is the one with the minimum value of the AIC/BIC

results, a time-varying inflation target model, and an inflation target driven by the structural shocks. From the multiple series for the inflation target, this exercise allows me to infer the best-fit series for the inflation target across the three models. Second, I explore the implications of a time-varying inflation target on exogenous monetary policy shocks, and its contribution to the U.S. macroeconomic dynamics, based on the results of the estimated model.[8]

2.3.1 The Model

I begin by summarizing the model economy and display the problems solved by firms and households. As is standard in the literature, all variables are log-linearized around their steady-state balanced growth path driven by deterministic labor-augmenting technological progress. As in the benchmark quantitative macroeconometric model of Smets and Wouters [2007], fluctuations are driven by seven exogenous stochastic disturbances: a shock to the growth rate of total factor productivity (TFP), an investment-specific technology shock, a risk-premium shock, a price-markup shock, a wage-markup shock, a government spending shock and a monetary policy shock. However, a shock to the inflation target is added on top of these shocks.

Households Similar to standard smaller models,[9] the economy is populated with a continuum of households with identical preferences that depend on hours worked and consumption. Each household makes a consumption decision and a capital accumulation decision, and it decides how many units of capital services to supply to firms. The sequence sequence of decisions during each period. These decisions are conveniently summarized by the dynamic Euler equation: consumption depends on past consumption because of habit formation, on expected future con-

[8]Once I find the best fitting series given these policy preferences, the model is estimated for different specifications of the feedback rule, across multiple specifications of the inflation target, and structural shocks, which allows me to explore the best-fit specification of the feedback rule. These results are included in the appendix.

[9]See, for example, Gali [2009].

sumption because consumers prefer to smooth consumption, on expected growth in hours worked because of non-separable preferences and on the ex-ante real interest rate of bonds that reflects the intertemporal substitution of consumption:

$$c_t = barc_1 c_{t-1} + (1 - \bar{c}_1) E_t c_{t+1} + \bar{c}_2 (l_t - E_t l_{t+1}) - \bar{c}_3 (r_t - E_t \pi_{t+1} + \epsilon_t^b) \qquad (2.5)$$

where the the parameters $\bar{c}_1$, $\bar{c}_2$ and $\bar{c}_3$ are functions of the growth rates in the steady state: $\bar{c}_1 = \frac{\lambda/\gamma}{1+\lambda/\gamma}$, $\bar{c}_2 = \frac{(\sigma_c - 1)(W_*^h L_*/C_*)}{\sigma_c(1+\lambda/\gamma)}$ and $\bar{c}_3 = \frac{1-\lambda/\gamma}{\sigma_c(1+\lambda/\gamma)}$. The term $\epsilon_t^b = \rho_b \epsilon_{t-1}^b + \eta_t^b$ is a time-varying disturbance representing the wedge between the nominal interest rate controlled by the central bank and the return on assets held by households. In the model, a positive shock increases the return on assets, making households forgo some consumption, which falls. Introducing this disturbance is a short-cut to capture unmodelled fluctuations in the degree of financial frictions. These frictions generate an external finance premium. The risk-premium shock works as an aggregate demand shock and generates a positive comovement between consumption and investment.The supply effect causes the cost of capital to rise, and therefore the value of capital and investment falls. Notice that when $h = 0$, this equation reduces to the traditional forward-looking consumption equation. A high degree of habit persistence will tend to reduce the impact of the real rate on consumption for a given elasticity of substitution. Due to the assumption that consumption and cash holdings are additively separable in the utility function, cash holding does not enter in any of the other structural equations.

Firms The economy is populated by a continuum of firms which produces a single final good. The final-good sector is perfectly competitive. The final good is used for consumption and investment by the households. The representative finished goods-producing firm bundles all the intermediate goods to produce the finished good. A shock affects the elasticity of substitution across differentiated inputs. This disturbance thus generates exogenous stochastic fluctuations in the market power of the intermediate goods suppliers and, in turn, in their desired

markup of price over marginal cost. This shock is therefore labelled the price-markup shock (or the cost-push shock). There is monopolistic competition in the markets for intermediate goods: each intermediate good is produced by a single firm. Each firms combine capital and labor to produce output. In this economy, firms utilize a certain share, represented by the parameter α, of capital (k_t^s) and labor(l_t) provided by households, to produce output (y_t). Output is affected by total factor productivity (ϵ_t^a) which follow an autoregressive process of order one, $\epsilon_t^a = \epsilon_{t-1}^a + \eta_t^a$. Firms also face some fixed costs in production, controlled by the parameter ϕ_p, which is one plus the share of fixed costs in production. The aggregate production function is given by

$$y_t = \phi_p(\alpha k_t^s + (1-\alpha)l_t + \epsilon_t^a) \tag{2.6}$$

Capital in this economy operate in a dynamic fashion, combining last periods capital plus new stock. However, the model includes capital utilization to track the actual usage of capital installed. Firm specific capital utilization is assumed to evolve such that current capital used in production (k_t^s) is a function of capital installed in the previous period (k_{t-1}) as well as the degree of capital utilization (z_t).

$$k_t^s = k_{t-1} + z_t \tag{2.7}$$

The accumulation of installed capital (k_t) comes from the dynamic flow of investment, with a share k_1 coming from last period's installed capital, and the rest from this period's investment plus the relative efficiency of these investment expenditures as captured by the investment-specific technology disturbance (ϵ_t^i). This shock may summarize the technology that transforms current and past investment into installed capital for use in the following period.

$$k_t = k_1 k_{t-1} + (1-k_1)i_t + k_2\epsilon_t^i \tag{2.8}$$

Since cost minimising households supply capital, the degree of capital utilization (z_1) will be a positive function of the rental rate of capital (r_t^k). As the rental rate of capital rises, households will forego consumption so they can reap higher profit in the next period. These nominal rates are simply derived from the partial derivates of the production function with each respective factor input.

$$z_t = z_1 r_t^k \tag{2.9}$$

To explicitly capture the degree of capital utilization, a paramter ψ is introduced. The degree of capital utilization is a positive function of the elasticity of capital utilization ($z_1 = \frac{1-\psi}{\psi}$), where ψ is normalized to be between 0 and 1. A high value of ψ will imply a high cost of changing the utilization of capital, and when ψ is very low, the marginal cost of changing the utilization of capital is constant, therefore the rental rate on capital will be constant. In the extreme case when ψ = 1, the utilization of capital will remain constant.

The monopolistically competitive firm in the goods markets minimizes costs such that the price mark up (μ_t^p) is equal to the difference between the operating marginal product of labor (mpl_t) and the real wage (w_t). The marginal product of labor comes from the first order conditions of the firms maximization problem, and is therefore a positive function of the capital labor ratio and the total factor productivity $mpl_t = \alpha(k_t^s - l_t) + \epsilon_t^a$.

$$\mu_t^p = mpl_t - w_t \tag{2.10}$$

Combining the equations for the $k - period$ forward looking profit for the firm, which include partial indexation to lagged inflation and price stickiness as per Calvo [1983], prices adjust sluggishly to their desired mark-up. This model has been widely used to characterize price-setting frictions. A useful feature of the model is that it can be solved without explicitly tracking the distribution of prices across firms.The assumption that all prices are indexed to either lagged inflation

or the steady state inflation rate ensures that the Phillips curve is vertical in the long run. The speed of adjustment to the desired mark-up depends on the degree of price stickiness, the curvature of the Kimball goods market aggregator and the steady-state mark-up. In equilibrium the steady state mark-up is itself related to the share of fixed costs in production through a zero-profit condition. A higher mark-up slows the speed of adjustment because it increases the strategic complementarity with other price setters. In a world with fully flexible prices and the price-mark-up shock set to zero, the NKPC reduces to the standard Gali [2009] formulation that the price mark-up is constant, or equivalently, that there are no fluctuations between the marginal product of labor and the real wage. Combining these elements gives rise to the augmented New-Keynesian Phillips curve:

$$\pi_t = \pi_1 \pi_{t-1} + \pi_2 E_t \pi_{t+1} - \pi_3 \mu_t^p + \epsilon_t^p \tag{2.11}$$

Since the parameters π_1, π_2 and π_3 are just functions of the degree of indexation, the steady state trend growth of GDP and the time preference parameter, inflation in this period (π_t) depends positively on past(π_{t-1}) and future inflation (π_{t+1}) and negatively on the current price mark-up. Inflation in the current period will be higher if there is a positive shock to the price-mark-up disturbance (ϵ_t^p), which follows an ARMA(1,1) process: $\epsilon_t^p = \epsilon_{t-1}^a + \eta_t^a - \mu_p \eta_{t-1}^a$, where μ_p is an IID normal price mark-up shock. The MA term is included to capture the high frequency fluctuations in inflation. The standard New-Keynesian Phillips Curve can be obtained by setting the indexation parameter (ι) to zero. Given the profit maximization condition, the rental rate of capital is negatively related to the capital-labor ratio and positively to the real wage (both with unitary elasticity):

$$r_t^k = -(k_t - l_t) + w_t \tag{2.12}$$

It is pertinent to mention that households own the capital stock, a homogenous factor of production, which they rent out to the firm-producers of intermediate

goods at a given rental rate of r_t^k.

I next move on to describe the labor market. The behavior of this market is similar to the goods market. Households act as price-setters in the labor market. In the monopolistically competitive labor market the difference between the real wage and the marginal rate of substitution between working and consuming ($mrs_t = \sigma_l l_t + \frac{c_t - \lambda/\gamma c_{t-1}}{1-\lambda/\gamma}$) will be the wage mark-up, where σ_l is the elasticity of labor supply with respect to the real wage and λ is the habit parameter in consumption:

$$\mu_t^w = w_t - mrs_t \tag{2.13}$$

Similar to the price stickiness, the labor market will have nominal wage stickiness, due to which real wages only adjust gradually to the desired wage mark-up:

$$w_t = w_1\pi_{t-1} + (1-w_1)(E_t\pi_{t+1} + E_t w_{t+1}) - w_2\pi_t + w_3\pi_{t-1} - w_4\mu_t^w + \epsilon_t^w \tag{2.14}$$

Real wage w_t is a function of expected and past real wages, expected, current and past inflation, the wage mark-up and a wage-markup disturbance (ϵ_t^w). In a model with perfectly flexible wages, $\xi_w = 0$, the real wage would be a constant mark-up over the marginal rate of substitution between consumption and leisure. In general, the speed of adjustment to the desired wage mark-up depends on the degree of wage stickiness (ξ_w) and the demand elasticity for labor, which itself is a function of the steady-state labor market mark-up ($\phi_w - 1$) and the curvature of the Kimball labor market aggregator (ϵ_t^w). When wage indexation is zero ($\iota_w = 0$), real wages do not depend on lagged inflation ($w_3 = 0$). Therefore, the deviation of the actual real wage from the wage that would prevail in a flexible labor market would be greater the smaller the degree of wage rigidity, the lower the demand elasticity for labor and the lower the inverse elasticity of labor supply (the flatter the labor supply curve). The wage-markup disturbance (ϵ_t^w) is assumed to follow an ARMA(1,1) process with an IID-Normal error term: $\epsilon_t^w = \epsilon_{t-1}^w + \eta_t^w - \mu_t^w \eta_{t-1}^w$. As in the case of the price mark-up shock, the inclusion of an MA term allows us

to pick up some of the high frequency fluctuations in wages.

Monetary Authority The model is closed by introducing a central bank that sets interest rates according to the following feedback rule:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)[\phi_\pi[\pi_t - \pi_t^T] + \phi_x x_t] + \epsilon_{R,t} \tag{2.15}$$

I consider two cases for the evolution of the time-varying inflation target. First, I constrain the inflation target to follow an AR(1) process, $\pi_t^T = \rho_\pi \pi_{t-1}^T + \epsilon_\pi$. One possible interpretation for the behavior of the inflation target is to capture discretionary movements in the inflation target. One reason why I name these shocks as discretionary movements is based on the views presented by Cook [1988] and Taylor [1993] who interpret any interest rate movements as deliberate actions taken by the Federal Reserve. Simply put, one could think of changes in the inflation target as a result of the monetary authorities' imperfect control. In this framework, the central bank systematically sets interest rates, and systematically sets the inflation target in each period but is unable to do so perfectly. Alternatively, the exogenous target model might be reinterpreted in line with the hypothesis presented in Sargent [2001] that Federal Reserve officials actively pushed inflation higher during the 1960s and 1970s in a futile effort to exploit a misperceived Phillips curve trade-off. Or one could think of changes in the inflation target as reflecting the uncertainty in the economy (Tetlow [2008]). In general, however, changes in the inflation target reflect deliberate actions of the monetary authority in my framework.

I also generalize the specification considered in Ireland [2005], and include all structural shocks in the economy to explain the movement in the inflation target.[10] However, unlike their model, I impose no prior restriction on the sign of the response coefficients, δ_j, and they are determined through estimation techniques.[11]

[10] I consider various combinations of this specification. However, the inflation target as an AR(1) outperforms all alternative cases. These results are available in the appendix.

[11] Once can show that a positive δ_j would imply an accommodating central bank, while a

I assume that the inflation target in this case is summarized as follows:

$$\pi_t^T = \rho_\pi \pi_{t-1}^T + \delta_a \epsilon_a + \delta_b \epsilon_b + \delta_g \epsilon_g + \delta_i \epsilon_i + \delta_w \epsilon_w + \delta_p \epsilon_p + \epsilon_\pi \tag{2.16}$$

The term $\epsilon_{r,t}$, may also represent 'discretionary' exogenous interest rate movements, which follow an AR(1) process, $\epsilon_{R,t} = \rho_r \epsilon_{R,t-1} + \eta_{r,t}$. Finally, the aggregate resource constraint is given by:

$$y_t = c_y c_t + i_y i_t + z_y z_t + \epsilon_t^g \tag{2.17}$$

where c_y, i_y and z_y are steady state consumption, investment and the capital utilization rate, respectively. Output is therefore used for consumption, investment and capital utilization z_t, whereas ϵ_t^g represents exogenous demand shocks, which are also affected by productivity shocks: $\epsilon_t^g = \rho_g \epsilon_{t-1}^g + \eta_t^g + \rho_{ga} \eta_{t-1}^a$.

To summarize, the model contains 14 endogenous variables: output, consumption, investment, value of the capital stock, installed stock of capital, stock of capital, capital utilization rate, real rental rate on capital, real marginal cost, real wages, hours worked, interest rate and the inflation target. In addition, eight exogenous autoregressive processes are introduced, with each including an iid-normally distributed error, total factor productivity, investment-specific technology, risk premium, demand shocks, price mark-up, wage mark-up, a monetary policy shock and shocks to the time-varying inflation target.

2.3.2 Baseline Results

In this section, I discuss the results of the estimated model, and compare them with the results presented in by Smets and Wouters [2007], which is re-estimated using Bayesian techniques.[12] In the first step, I shortlist the inflation target series

negative δ_j would imply an aggressive central bank.

[12]The model presented in the previous section is estimated using Bayesian estimation techniques using Monte-Carlo Markov-Chain (MCMC) sampling methods. In general MCMC is a class of methods in which we can simulate draws that are slightly dependent and are approximated from a (prior) distribution. These draws are used to calculate quantities of interest for the

with the highest likelihood of matching the data, by estimating two versions of the model using the nine estimated series of the inflation target, and comparing it with the baseline fixed inflation target model.[13] The modified harmonic mean estimator is used to calculate the BIC/AIC factor, and to identify the complete model that best fits the data. Having selected the time series for the inflation target that best matches the observables, I then focus on estimating three versions of the model. I estimate a fixed inflation target model, a time-varying inflation target model, and a model with the time-varying target driven by structural shocks. Table 2.2 summarizes the fit of these three models. My results suggests that a model with an AR(1) time-varying target fits the data better than a model with a time-varying target driven by structural shocks, but a model with a time-varying inflation target strictly fits the data better compared to a constant inflation target model.

Table 2.2: Model Fit

Model	Parameters	ML	BIC	AIC
Fixed Target	36	-963.61	2100.9	1999.9
AR(1) TV target (TV - I)	39	-810.09	1817.1	1698.2
TV target with shocks (TV - II)	45	-921.27	2069.8	1932.5

The table presents the value of the BIC test for a fixed inflation target model, a model with a time-varying inflation target which follows an AR(1) process, and a time-varying target driven by the structural shocks.

I now focus on the estimated parameters from these three models. First, table 2.3 focuses on the estimates of the structural parameters. The adjustment cost parameter, habit formation, probability of wage change, price indexation, and the share of labor in production are estimated to be around 6.2, 0.78, 0.65, 0.18

(posterior) distribution. The Metropolis-Hastings algorithm allows us to get a complete picture of the posterior distribution, and to evaluate the marginal likelihood of the model, which will be used to compare model fit as normally done in the literature. The procedure for the MH algorithm as well as the prior selection is described fully in the appendix.

[13] I only focus on the results of the best fit series in the section, leaving the estimation robustness across different specifications in the appendix. The robustness exercises allow me to identify the (minor) relationship between structural shocks and monetary policy shocks, and to compare my results with other specifications.

and 0.25, respectively. The fixed target model suggests that firms reset prices every six months, while both time-varying target models suggest that firms reset their prices more often, and the price reset time is almost every 2.5 months. Wage indexation is also estimated to be lower in both time-varying inflation target models. The posterior mean of the fixed cost parameter is estimated to be much higher than assumed in the prior distribution (1.65) across the three models, but the intertemporal elasticity is estimated to be similar to the prior (1.5), and similar across the three models. The elasticity of labor supply under the fixed target model and under a time-varying target model suggests a value around 2, which is quite different from the prior.

Table 2.3: Prior and Posterior Estimation of the Structural Parameters

Parameters	Prior	Dist.	Fixed	TV - I	TV - II
φ	4.2	Normal	6.1	7.2	6.65
σ_c	1.56	Normal	1.58	1.4	1.6
λ	0.67	Beta	0.78	0.8	0.78
ϵ_w	0.672	Beta	0.66	0.63	0.67
σ_l	1.404	Normal	1.27	1.52	2.27
ϵ_p	0.61	Beta	0.55	0.59	0.60
ι_w	0.5	Beta	0.63	0.52	0.36
ι	0.5	Beta	0.2	0.13	0.18
ψ	0.5	Beta	0.5	0.33	0.27
ϕ_p	1.25	Normal	1.67	1.68	1.55
α	0.36	Normal	0.26	0.36	0.29

The table presents the prior and the posterior estimates of the structural parameters. The columns denote the results from estimating each type of model, 'Fixed' for the fixed inflation target model, 'TV - I' represents a model with a time varying inflation target with structural shocks, while 'TV - II' represents a model with an AR(1) inflation target.

Table 2.4 focuses on estimates of the monetary policy parameters. The mean of the long run reaction coefficient to inflation is estimated to be relatively high and is around 2.5 under a fixed target model, and 2.8 and 3 in both time-varying inflation target models. There is a considerable degree of interest rate

smoothing, as the mean of the coefficient on the lagged interest rate is estimated to be 0.81 under all three models. Policy does not appear to react very strongly to the level of the output gap (0.09). The persistence of monetary policy shocks is estimated to be 0.32 in the fixed target model, 0.22 in the time-varying target model, where the target is driven by structural shocks, and 0.17 in the time-varying target model with the AR(1) specification. Standard errors of monetary policy shocks are estimated to be 0.26 in the fixed target model, and 0.22 in both time-varying target models. The process for the inflation target is highly persistent, at around 0.95, and the standard deviation is 0.07 under both specifications of the inflation target. Since the shock to the inflation target is much more persistent than an exogenous shock to the interest rate, it may explain the persistent changes in the interest rate at longer horizons.

Table 2.4: Prior and Posterior Estimation of the Policy Parameters

Parameters	Prior	Dist.	Fixed	TV - I	TV - II
ρ_r	0.25	Beta	0.81	0.8	0.81
ρ_π	0.9	Beta	-	0.96	0.95
ρ_m	0.37	Beta	0.32	0.23	0.18
ϕ_π	3	Normal	2.55	2.82	3
ϕ_y	0.05	Normal	0.15	0.09	0.09
σ_m	0.09	IG	0.26	0.25	0.25
σ_π	0.27	IG	-	0.07	0.07
δ_a	0	Normal	-	0.0053	-
δ_g	0	Normal	-	0.0090	-
δ_b	0	Normal	-	-0.0073	-
δ_i	0	Normal	-	0.0019	-
δ_w	0	Normal	-	0.0019	-
δ_p^p	0	Normal	-	-0.0077	-

The table presents the results of the prior and the posterior estimates of the monetary policy parameters. The columns denote the results from estimating each type of model, 'Fixed' for the fixed inflation target model, 'TV - I' represents a model with a time varying inflation target with structural shocks, while 'TV - II' represents a model with an AR(1) inflation target.

Estimates of the main macroeconomic variables are summarized in table 2.5. The posterior mean of the steady-state inflation rate over the full sample is around 3 percent on an annual basis, as estimated in Smets and Wouters [2007]. The mean of the discount rate is estimated to be quite small (0.65 percent on an annual basis). For the time-varying target model, the steady-state inflation rate over the full sample is around 2.5 percent on an annual basis. The trend growth rate is estimated to be around 0.60, which is approximately the average growth rate of output per capita over the sample. The implied mean steady-state nominal and real interest rates are, respectively, about 6 percent and 3 percent on an annual basis.

Table 2.5: Prior and Posterior Estimation of the Steady State Variables

Parameters	Prior	Dist.	Fixed	TV - I	TV - II
$\bar{\pi}$	0.67	Gamma	0.67	0.67	0.55
$\bar{l}$	0.69	Normal	0.13	0.81	1.58
$\bar{\gamma}$	0.5	Gamma	0.60	0.67	0.67
$100(\beta^{-1}-1)$	0.21	Gamma	0.25	0.12	0.19
$\bar{\pi}^T$	0.53	Gamma	-	0.47	0.53

The table presents the results of the prior and the posterior estimates of the underlying steady state variables. The columns denote the results from estimating each type of model, 'Fixed' for the fixed inflation target model, 'TV - I' represents a model with a time varying inflation target with structural shocks, while 'TV - II' represents a model with an AR(1) inflation target.

Productivity, demand, inflation mark-up and wage mark-up shocks are estimated to be the most persistent, with persistence greater than 0.90 across the three models estimated. The high persistence and the standard deviation of productivity and demand (greater than 0.40 across the three models) implies that at long horizons, most of the forecast error variance of the real variables will be explained by those two shocks. Investment specific technology and finance premium shocks are estimated to be less persistent, with persistence and standard deviation around 0.60, and 0.25 respectively. Investment specific technology has

standard errors of around 0.50, while finance premium shocks have standard errors of around 0.30 across the three models.

Table 2.6: Prior and Posterior Estimation of Shock Processes

Parameters	Prior	Dist.	Fixed	TV - I	TV - II
ρ_a	0.97	Beta	0.98	0.96	0.97
ρ_b	0.21	Beta	0.13	0.34	0.25
ρ_g	0.85	Beta	0.97	0.96	0.96
ρ_q	0.36	Beta	0.7	0.64	0.64
ρ_m	0.37	Beta	0.32	0.22	0.17
ρ_p	0.87	Beta	0.99	0.98	0.99
ρ_w	0.74	Beta	0.97	0.85	0.96
σ_a	0.53	IG	0.46	0.45	0.48
σ_b	0.29	IG	0.27	0.23	0.25
σ_g	0.52	IG	0.53	0.52	0.52
σ_q	0.65	IG	0.48	0.48	0.50
σ_m	0.09	IG	0.26	0.23	0.22
σ_p	0.09	IG	0.13	0.15	0.15
σ_w	0.26	IG	0.27	0.27	0.26

The table presents the results of the prior and the posterior estimates of the shock processes. The columns denote the results from estimating each type of model, 'Fixed' for the fixed inflation target model, 'TV - I' represents a model with a time varying inflation target with structural shocks, while 'TV - II' represents a model with an AR(1) inflation target.

2.4 The Dynamics of the U.S economy

Using the results of the estimated model, I examine the quantitative implications of a time-varying inflation target on exogenous monetary policy shocks. I study the role of the time-varying inflation target in generating additional volatility during the pre-Great Moderation era. Finally, I present policy implications of exogenous shocks to the interest rate by computing the sacrifice ratios of the U.S. economy, comparing exogenous shocks to the inflation target with exogenous changes in the interest rate.

2.4.1 A Tale of Two Shocks

Exogenous Shocks to the Interest Rate

To quantify the impact of a time-varying inflation target on the behaviour of the exogenous monetary policy shocks, I compare the time series properties of the exogenous monetary policy shocks generated by a fixed target model with this series, generated under a time varying inflation target model. First, I focus on comparing the variance of the raw series for the policy shocks generated under both specifications of the time-varying inflation target, with the series generated under a fixed inflation target model. Second, to compare the variance and the evolution of these three series over time, I estimate a stochastic volatility model. Third, I take the variance decomposition of exogenous monetary policy shocks to the variation in inflation, output, hours and interest rate based on a fixed target model, and compare the variation of these variables under the same shock estimated in a time-varying inflation target model.

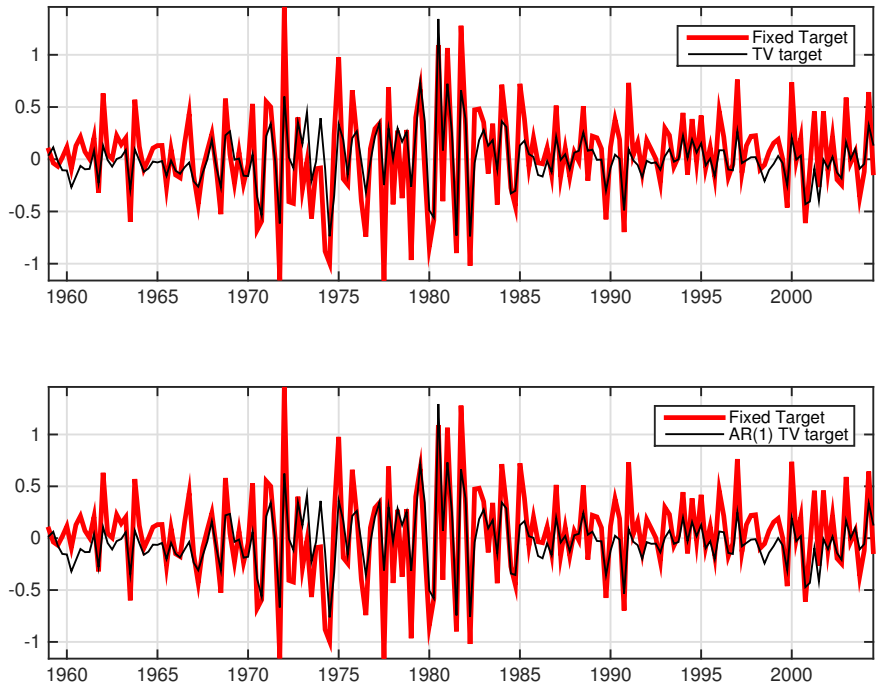
A comparison of the raw series for the exogenous monetary policy shocks generated across the three models suggests that including the inflation target considerably reduces the variance of the exogenous monetary policy shocks. In my framework, roughly 47% of the volatility in monetary policy shocks could be attributed to a time-varying inflation target, with this reduction robust across various specifications of the inflation target.[14] The time-varying inflation target model explains approximately 60% volatility of the exogenous monetary policy shocks in the pre-Volcker period, suggesting that a large proportion of exogenous shocks observed during the period could be attributed to changes in a time-varying inflation target.

The largest reduction in the volatility of exogenous monetary policy shocks occurs during the 1973 and between the 1980 - 1982 time period, corresponding with the dates when the most important policy changes took place, as presented

[14]Importantly, this reduction is much larger than the outcome under other misspecifications in the monetary policy rule considered in the appendix.

in Boivin [2005]. Potentially, the high degree of economic uncertainity during the pre-Volcker period could have caused the FOMC to shift its inflation target frequently, resulting in volatile interest rates. In this context, my results complement the reasons behind the variation in interest rates pointed out by Cook [1988] by suggesting that changes in the inflation target may be responsible for some of the important changes in monetary policy during these dates, an extension that is missing from fixed inflation target models. Therefore, the standard identification exercises that use a fixed target model to estimate monetary policy shocks may have overestimated the variance, and the contribution of monetary policy shocks to the macroeconomic dynamics (see, for example, Christiano et al. [2005], Gali [2009] and Smets and Wouters [2007]). These results are plotted in Figure 2.2.

Figure 2.2: Comparing Policy Shocks



This figure plots traditional and pure monetary policy shocks. Monetary policy shocks in the top panel represent the residual from an inflation target driven by structural shocks, while the second panel represent the residuals from the inflation target following an AR(1) process. The solid red lines plot exogenous monetary policy shocks based on a fixed inflation target model.

Second, Justiniano and Primiceri [2008] suggests that structural shocks may vary in size over time, especially when comparing the period before and after the Great Moderation. To align my findings with theirs, I examine whether shocks to the time-varying inflation target correlate with the timing of exogenous shocks to the interest rate., both of which are allowed to vary over time. I use the generated series of the exogenous shocks to the interest rate under a fixed inflation target model, and under the two time-varying inflation target models, to estimate an unobserved components model with moving average volatility. For comparison, I also estimate a model using the series of the shocks to the inflation target. I use the standard Gibbs sampler with 200,000 draws from the posterior distribution,

after a burn-in period of 10,000. Using this technique I estimate the following specification:

$$j_t = \epsilon_t^j \tag{2.18}$$

$$\epsilon_t^j = \mu + \psi_1 u_{t-1}, u_{t-1} \sim N(0, e^{h_t}) \tag{2.19}$$

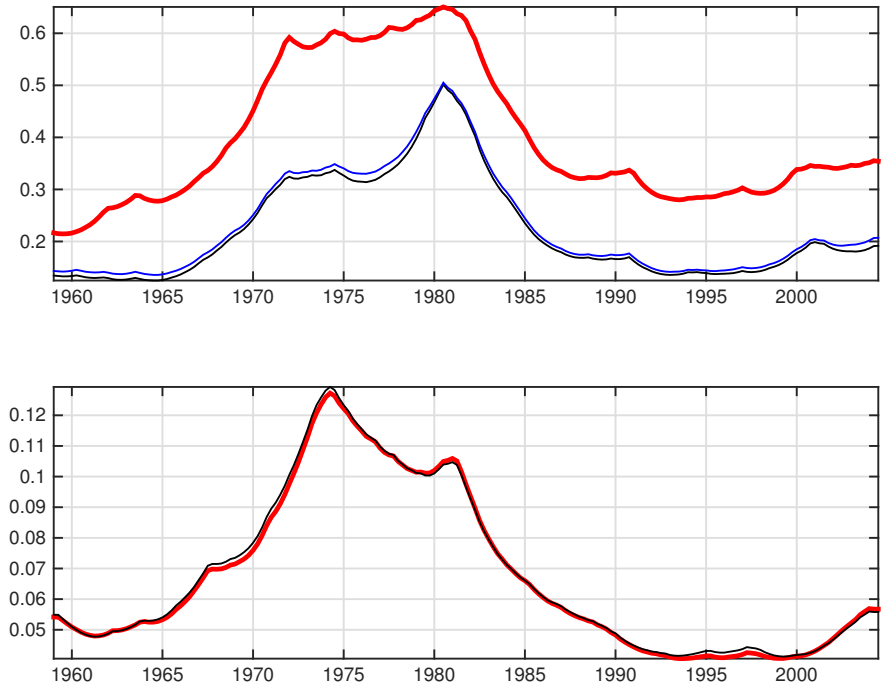
$$h_t = \mu_h + \phi_h(h_{t-1} - \mu_h) + \epsilon_t^h, \epsilon_t^h \sim N(0, \sigma_h^2) \tag{2.20}$$

where ϵ_t^j is the time series for the shocks, and $|\phi_h| < 1$. The errors u_t and ϵ_t^h are independent of each other for all leads and lags.[15]

Figure 2.3 plots the results generated by this model. Estimates from the stochastic volatility model suggest that the variance of exogenous shocks to the interest rate under a fixed inflation target model gradually rises from 1960 through to 1972, remaining large till the early 1980s, and falls sharply from the early 1980s. This is line with the findings presented in Justiniano and Primiceri [2008] who have highlighted the high variance of these shocks during the pre-Volcker period. The time-varying variance of the inflation target follows a similar pattern, with the largest rise coming in the first half of the 1970s, and gradually falling during Volcker's disinflation. This exercise suggests that shocks to the inflation target were most volatile during the 1973 through to 1978 period and 1980 through to 1981 period. These dates correspond to the findings presented in Justiniano and Primiceri [2008], Boivin [2005] and Romer and Romer [1989], and the most important changes in the inflation target seem to largely explain important changes in the interest rate. Since these two shocks are, by construction, orthogonal in the model, this finding justifies that the exogenous monetary policy shock may be misidentified and biased, and shocks to the inflation target may explain a lot of variation attributed to exogenous monetary policy shocks. Therefore, this framework presents a novel contribution to the characterization of changes in monetary policy, which has traditionally been attributed to exogenous and unexplained changes in the reaction function.

[15]Further details of estimating this process can be found in Chan [2013].

Figure 2.3: Comparing Policy Shocks - Stochastic Volatility

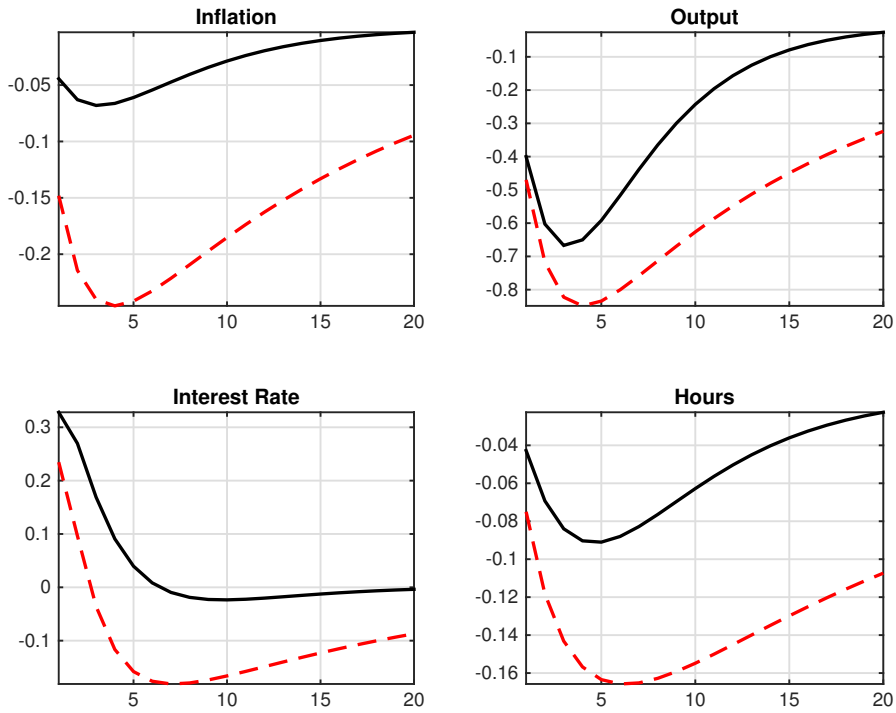


This figure plots traditional and pure monetary policy shocks in a stochastic volatility setting. The first panel plots the time-varying series of the exogenous shocks to the interest rate (red line), and exogenous shocks under a time-varying inflation target model (blue and black lines). The second panel plots the time-varying variance of exogenous shocks to the inflation target (red and black line).

Third, in order to compare the behavior of exogenous interest rate changes generated by a fixed inflation target model with those generated by a time-varying inflation target model, I compare the decomposition of variance and the dynamic responses of inflation, output, labor hours and interest rates. I simulate the model with estimates of monetary policy shocks generated from the fixed inflation target model, and compare with simulations of the model calibrated with results from the time-varying inflation target model, while fixing the structure and the behavioural side of the economy. Simply put, the only difference between the two models I compare is the parameterization of the monetary policy shocks. Figure 2.4 shows

the effect on inflation, output and hours and interest rate, simulated with the purified exogenous interest rate movements and traditional exogenous interest rate shocks.

Figure 2.4: The Dynamics of the Inflation Target - Shock Decomposition



This figure plots the impulse responses of inflation, output, interest rates and hours to a an exogenous shock to the interest rate. The red dotted lines represent IRF's of a traditional monetary policy shock as estimated by a model with a fixed inflation target. The solid black lines represent IRFs of a traditional monetary policy shock as estimated by a model with a time-varying inflation target.

The impulse response of inflation, output, hours and interest rate to exogenous monetary policy shocks estimated from a time-varying inflation target model suggest a damper response, compared to the response of these variables generated by an exogenous monetary policy shock estimated from a fixed inflation target model. This is due to the considerable lower volatility of the exogenous shocks under the time-varying target model, causing inflation, interest rate and hours

to fall by less as compared to their movement under a fixed target model. The hump shaped response of output remains intact and falls by less under the purified exogenous interest rate shocks, returning to steady state quickly. The decomposition of variance in tables 2.7 and 2.8 suggests that the reduction in volatility of the exogenous interest rate shocks leads to a 12% lower response in interest rate, which causes a fall of 27% in hours, 30% in inflation and around 24% in output.

Table 2.7: Variance Decomposition: Fixed Target Model

Variable	ϵ_t^a	ϵ_t^b	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w
Hours	5.55	1.92	7.56	7.77	1.78	15.18	60.25
Interest Rate	3.71	1.99	1.52	12.44	15.88	27.39	37.07
Inflation	1.80	0.29	0.37	3.20	2.83	43.00	48.52
Output	14.01	21.98	22.06	20.82	5.40	6.12	9.61

The table presents the variance decomposition of the seven structural shocks to inflation, interest rate, hours and output in the fixed target model.

Table 2.8: Variance Decomposition: Counterfactual Analysis

Variable	ϵ_t^a	ϵ_t^b	ϵ_t^g	ϵ_t^i	ϵ_t^r	ϵ_t^p	ϵ_t^w
Hours	5.58	1.93	7.60	7.80	1.30	15.25	60.54
Interest Rate	3.80	2.04	1.55	12.73	13.96	28.01	37.92
Inflation	1.81	0.29	0.37	3.23	2.00	43.36	48.94
Output	14.21	22.29	22.36	21.11	4.08	6.21	9.74

The table presents the variance decomposition of the seven structural shocks to inflation, interest rate, hours and output by calibrating the fixed target model with the parameters obtained from the model with a time varying inflation target.

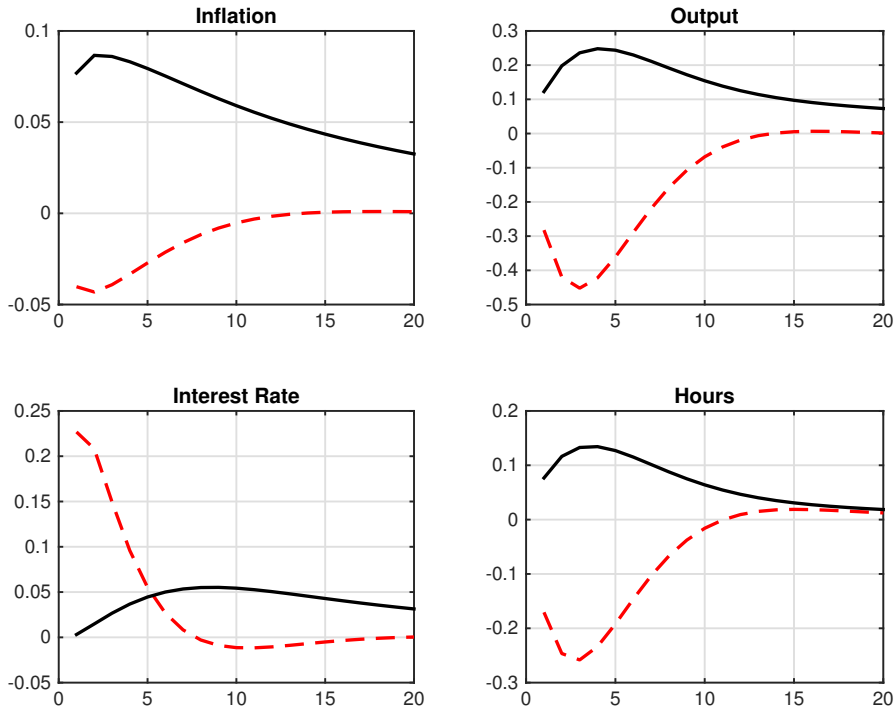
This section presents evidence that supports the hypothesis that a time-varying inflation target may explain a large portion of the variation attributed to exogenous monetary policy shocks. In this context exogenous monetary policy shocks seem to be largely contaminated by changes in the inflation target, and therefore overestimate the true effects of exogenous monetary policy shocks in a macroeconomic model. Critically, the behaviour of the time-varying shocks to the

inflation target corresponds with the behaviour of the shocks to the exogenous interest rates. This is especially true around the periods corresponding to the dates when the largest changes in monetary policy took place as identified in the existing literature. These findings call for a re-evaluation of the macroeconomic effects of exogenous shocks in a DSGE model by considering time-varying reaction functions as further clarifying the behaviour of monetary policy.

Exogenous Shocks to the Inflation Target

Having highlighted the impact of the time-varying inflation target on the properties of the exogenous changes in the interest rate, I focus on the impact of this shock on macroeconomic dynamics. Figure 2.5 compares the response of interest rate, inflation, output and hours under the estimated shock to the inflation target with a shock to the interest rate.

Figure 2.5: The Dynamics of the Inflation Target - Impulse Responses



The figure represents the IRF's of traditional monetary policy shocks (red dotted line) and shocks to the inflation target (black solid line)

A positive shock to the inflation target initially raises inflation, interest rates, output and hours. In the first 8 periods, inflation rises by 7-basis-points, output by 21-basis-points interest rates by 3-basis-points and hours by 11-basis-points. Since agents in this model are unable to distinguish between transitory exogenous interest rate shocks and persistent exogenous inflation target shocks in the short run, the perceived inflation target deviates from the central bank's chosen target. This leads to an unanchoring of inflation expectations, causing inflation to rise persistently and interest rates to start rising. Due to the forward-looking nature of inflation, economic agents expect higher inflation in the next period, some of which is partially cancelled by the past indexation in the Phillips curve. Since the shock is very persistent, inflation continues to rise, until interest rates rise rapidly. This effect causes the inflation response to be hump-shaped. The interest

rate response by the monetary authority is not sufficient to close this inflation gap, since inflation expectations have been unanchored. Hours behave analogously to inflation in this model: firms, while setting wages, are forward looking but due to the presence of some partial indexation to the past wage rates display a hump-shaped response. Since the change in policy is implemented gradually and expectations have time to adjust, the output effects of the change in inflation are much smaller. Even after 20 periods, all variables are above steady state: inflation is still 3 basis points above steady state, interest rates are 3-basis-points above steady state, output is 7-basis-points above steady state and hours are 1.8-basis-points above steady state. While inflation expectations become relatively more anchored as compared to the first 8 periods as the inflation target returns to steady state, the model suggests that inflation expectations are not fully anchored even after 20 periods, due to the permanent nature of the shock to the inflation target.

My findings suggest that the propagation effect of a shock to the inflation target is very different compared to the effect of an exogenous interest rate shock, and causes a hump-shaped response of inflation, output, hours and the interest rate. As private sector inflation forecasts in the United States (where monetary policy is not guided by an inflation target) are highly correlated with a moving average of lagged inflation, while this correlation is essentially zero in a number of countries with formal inflation targets (Levin et al. [2004]), my findings suggest that the output costs of changing an inflation target may be very low. This issue is examined in detail in the last section. Moreover, since the shock to the inflation target is implemented gradually, it may reconcile evidence of the 'price puzzle' introduced in Eichenbaum [1992]. Therefore, my results suggest that a price puzzle may arise since these two policy shocks are often combined.[16]

[16]My framework and analysis is very different from the one presented Bache and Leitemo [2008], who estimate a VAR model based on artificial data generated from a stylized model. My framework uses a more representative model of the U.S. economy, and relies on estimated parameters rather than a parameterized model, and therefore paints a more realistic picture of the role of policy shocks compared to other structural shocks observed in the U.S. dynamics.

2.4.2 Subsample Estimates and the Great Moderation

In this section, I assess the contribution of the shock to the inflation target on the high macroeconomic volatility experienced by post-war U.S. This exercise is motivated by empirical evidence presented in Stock and Watson [2002] who identify a large decline in the volatility of aggregate economic activity, employment and inflation since the early 1980s. Previous studies offer several potential explanations for this "Great Moderation." Some studies point to evidence that output volatility fell more than sales volatility, highlighting the potential role of better inventory control methods (see, for example, Kahn et al. [2002]). Another line of research stresses "good luck" in the form of smaller exogenous shocks (see, for example, Stock and Watson [2002]). Better monetary policy played an important role in the reduction in volatility, and therefore moving to a 'better' monetary policy regime has large welfare effects (see, for example, Clarida et al. [2000]).[17] However, my framework generalizes better policy to include a stable inflation target observed during the post-Volcker era.

My estimates suggest that the process for the inflation target is more persistent, compared to a standard exogenous shock to the interest rate. Moreover, shocks to the inflation target are estimated to be almost twice as volatile during the sample from 1959 through to 1979:II, compared to the period 1984 through to 2004:IV. This channel may have played an important role in generating the excess volatility observed during the former time period. To make a fair comparison with the baseline Smets and Wouters [2007] model, I compare the standard deviation of inflation and output growth in the data for the entire time period, by computing the theoretical moments of the model. This allows me to first compare the fit of my extended model with actual dynamics observed in the data, before proceeding with policy counterfactuals. In the baseline case, the model is also estimated for 1959 through to 2004:IV. I re-estimate the model for the 1966 through to 2004:IV time period in oder to compare with the Smets and Wouters [2007] sample. Table

[17] Summers [2005] perform a cross country analysis which also backs the role of monetary policy in reducing the macroeconomic volatility across countries.

2.9 summarizes these results.

Table 2.9: Model Fit

Variable	Data	SW	TVE	TV
Inflation	0.61 - 0.62	0.57	0.61	0.51
Output	0.89 - 0.85	0.94	1.45	1.28

The table compares the fit of the estimated model with the data, the Smets and Wouters [2007] model and the time-varying inflation target model with different sample selection. Under the data column, the first value presents the value for the 1959:I - 2004:IV sample, while the second value presents the value for the 1966:I - 2004:IV samples. SW is the baseline Smets and Wouters [2007] model. TVE is the time-varying inflation target model for the 1959:I - 2004:IV sample, while TV is the time-varying inflation target model for the 1966:I - 2004:IV samples.

My results suggest that the extended model fits the data on inflation better from 1959:I through to 2004:IV compared to the results found in Smets and Wouters [2007], which fit the data on inflation better for the 1966:I through to the 2004:IV period. To compare the extended subsample with the baseline Smets and Wouters [2007] case, I re-estimate the model and compare the fit for the subsamples from 1959:I to 1979:II, 1966:I through to 1979:II, and from 1984:I - 2004:IV. The extended model improves the fit of inflation for 1959:I through to 1979:II, but both output and inflation volatility are overestimated in the second sample in the time-varying inflation target model. These findings suggest that a time-varying inflation target fits the data better in the first sample, as compared to the second sample, irrespective of the initial date of the first subsample. Therefore, the behaviour of inflation in the first subsample is better matched in the model that includes a time-varying inflation target, and may suggest a possibly important exclusion from current models that analyze this sample. This finding also verifies the evidence suggested by Belaygorod and Dueker [2005], who do not find the inflation target to be important in the post-1984 period.

Table 2.10: Model Fit: First Subsample

Variable	Data	SW	TVE	TV
Inflation	0.69 - 0.55	0.81	0.74	1.07
Output	1.02 - 1.02	1.13	1.7	1.56

The table compares the fit of the estimated model with the data, the Smets and Wouters [2007] model and the time-varying inflation target model with different sample selection. Under the data column, the first value presents the value for the 1959:I - 2004:IV sample, while the second value presents the value for the 1966:I - 2004:IV samples. SW is the baseline Smets and Wouters [2007] model. TVE is the time-varying inflation target model for the 1959:1 - 1979:II sample, while TV is the time-varying inflation target model for the 1966:I - 1979:II sample.

Table 2.11: Model Fit: Second Subsample

Variable	Data	SW	TVE
Inflation	0.25	0.34	0.56
Output	0.55	0.73	0.99

The table compares the fit of the estimated model with the data, the Smets and Wouters [2007] model and the the time-varying inflation target model with different sample selection. SW is the baseline Smets and Wouters [2007] model. TVE is the time-varying inflation target model for the 1984:1 - 2004:IV sample.

I use this model to quantify the contribution of the inflation target to the macroeconomic volatility observed during the pre-Volcker era. For the purposes of this exercise, I use the estimation results of the first sample, and discuss the contribution to economic volatility of the various potential sources of disturbances. I quantify the contribution of the economic structure, preceded by the contribution of the volatility of the structural shocks, followed by the contribution of monetary policy to the economic volatility. I add a layer of complication by discussing the consequences for the volatility of the economy if the inflation target had remained as volatile as it was in the first sample, and study the implications by comparing it with a period when the inflation target is estimated to have stabilized, and

remained within a narrower band of 1.5 to 2.5%. To estimate the contribution of these counterfactual scenarios, I sequentially replace the structural parameters, the policy parameters, the structural shocks, and exogenous shocks to the inflation target during the first sample, with the estimates of the second sample.[18]

Table 2.12: Counterfactual Analysis

Variable	Data	TVE	Shocks	Monetary Policy	Inflation Target	Structure
Inflation	0.25	0.5	0.84	0.56	0.78	0.57
Output	0.55	1.1	1.39	1.00	1.00	1.01

The table decomposes the sources of the Great Moderation into the contribution of shocks, monetary policy, inflation target and structural parameters. The first column presents the data for the 1984:1 - 2004:IV sample, with the second column titled TVE presents the model implied theoretical moments for the 1984:1 - 2004:IV sample. The column titled 'Shocks' presents the contribution of structural shocks, if the U.S economy experienced in the 1984:1 - 2004:IV sample experienced the shocks of the 1959:1 - 1979:II sample. The column titled 'Monetary policy' focuses on the contribution of monetary policy to the macroeconomic volatility, while the column 'TVE' isolates the volatility from a time-varying inflation target of the 1959:1 - 1979:II with the second sample. The column on 'Structure' presents the contribution of the transmission mechanism to the Great Moderation.

The results illustrate an important channel of 'bad' monetary policy, one of the reasons behind the increased macroeconomic instability in the first sample. If the target had remained as volatile as it was in the first sample, inflation would have been 39% more volatile. This is close to the estimates suggested in Castelnuovo [2012c]. This channel suggests that policy mistakes that occurred in the first subsample may also be extended to include volatile endogenous movements in the feedback rule. Moreover, of the total movement in inflation volatility, the feedback effect if the Fed responded to structural shocks contributed to a little less than 2% of the inflation volatility. There are two important consequences of this

[18]In order to be consistent with my previous findings, I use the following two subsamples 1959:I - 1979:II, and from 1984:I - 2004:IV for this section.

result. First, even if the model had wrongly rejected the opportunistic approach to disinflation hypothesis, my results suggest that this channel played a minor role in contributing to the macroeconomic volatility of that period. Second, most of the observed volatility in inflation is due to a volatile inflation target, represented by shocks to the inflation target. One can analyze this evidence in a slightly different light: in the first sample, the inflation target was volatility, for the reasons explored in the previous section, lead to an unanchoring of inflation expectations. However, in the second sample the inflation target rarely moved outside a tight range, increasing the Fed's credibility, and the possible reasons behind the anchoring of inflation expectations, supporting the main findings made in Tetlow [2008]. In this context, the time-varying systematic policy rule may help account for the apparent rise and fall in economic volatility experienced by the U.S. economy, complementing the findings made in Primiceri [2005].

The monetary authorities' response coefficients to inflation and output, and changes in the structure of the transmission mechanism, play a minor role in the Great Moderation, a result which is similar to the findings in Smets and Wouters [2007]. Had structural shocks remained as volatile as they had been in the first sample, inflation would have been 54% more volatile, confirming the evidence found in Sims and Zha [2006], lending further support to the good luck hypothesis as the major explanation for the resulting rise in macroeconomic stability.

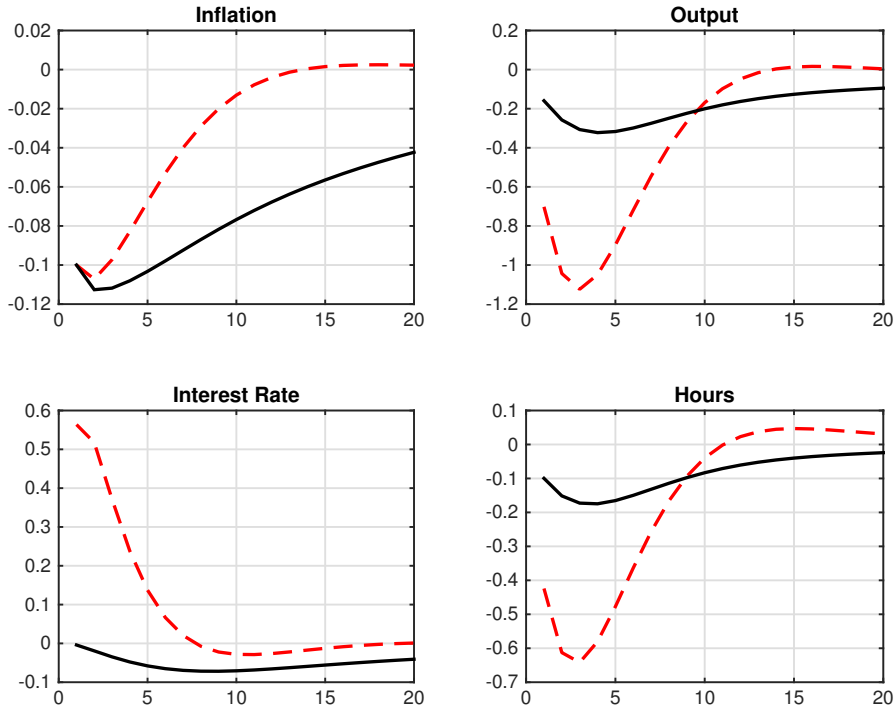
2.4.3 Policy Experiment and the Sacrifice Ratio

In a preceding section, I highlighted that the impact on the economy of changes in monetary policy due to changes in interest rate is different to the impact of changes in the inflation target. These two modes of changing the interest rate could be treated as potentially different tools to achieve the same macroeconomic objective. To compare these two shocks, I normalize their effect such that both types of policy changes represent ways to cause disinflation. Specifically, I normalize the effect of the shocks in such a way that both shocks are contractionary, and are of the same

size in terms of their effect on inflation. The impulse responses for output, hours and interest rates are multiplied by the same normalizing constant. I use these normalized responses in order to compare the welfare consequences of using these as policy tools. In general this suggests a novel policy perspective on the economic costs of changing the inflation target compared to random perturbations in the interest rate.

In figure 2.6, I plot the normalized impact of monetary policy shocks and the normalized impact of shocks to the inflation target. Inflation is normalized to be -10-basis-points on impact. Under an exogenous shock to the inflation target, inflation falls for four periods before gradually rising towards steady state, compared to a one period fall before moving towards steady state under a shock to the exogenous interest rate. The shock is so persistent that even in the twenty periods considered, inflation does not return to steady state, compared to the 12 periods it takes to return to steady state under an exogenous shock to the interest rate. The corresponding decline in output and hours is higher under a exogenous change to the interest rate. Under a exogenous change in the interest rate, output falls by 80-basis-points in the first 8 periods, returning to zero in 15 periods. Under a shock to the inflation target, output falls to around 27-basis-points, but is 9 basis points below steady state even after 20 periods. This result differes from Ireland [2005], who finds that the effect on output of a shock to the inflation target is largely transitory. Based on these results, a shock to the inflation target induces a gradual change in the interest rate, with the exogenous shock producing a sharp rise, and fall to steady state values. Labor hours fall by 44-basis-point under a movement in the exogenous interest rate, and only fall by 14-basis-point under a shock to the inflation target. Similar to output, hours worked return to steady state after about 10 periods under a discretionary interest rate shock, while remaining persistently low at 2.5-basis-points below steady state after a shock to the inflation target.

Figure 2.6: The Dynamics of the Inflation Target - Impulse Responses of Normalized Shocks



The figure represents impulse response functions of normalized traditional monetary policy shocks (red dotted line) and shocks to the inflation target (black solid line).

Since the dynamic response of output, labor hours and inflation to a shock to the inflation target is very different from an exogenous shock to the interest rate, each type of policy implies economic trade-offs. I tabulate these trade-offs by comparing the sacrifice ratio implied by each type of shock. I calculate the sacrifice ratio of the two monetary policy shocks by dividing the cumulative response of output to each shock by the cumulative response of inflation. For a discretionary interest rate shock, the sacrifice ratio is calculated to be around 11.4, while the sacrifice ratio is calculated to be 2.5 for the discretionary inflation target shock. In lost-output terms, it costs 4.5 times more, when using discretionary interest rate changes as compared to discretionary inflation target changes, to cause disinflation. In order to gauge the change in labor hours, I find a sacrifice ratio for the hours

worked by dividing the cumulative response of change in hours by response of inflation. For a discretionary interest rate shock, the sacrifice ratio is calculated to be around 5.4, for the discretionary inflation target shock, the sacrifice ratio is calculated to be 1.14. It costs 4.7 times more worker hours to decrease inflation by the same amount when using discretionary interest rate changes, compared to discretionary inflation target changes.

First, the sacrifice ratios contribute to the findings made in Fuhrer [1994], Wascher et al. [1999], Ball and Reyes [2007] and Cecchetti and Rich [1999] who find different estimates of the sacrifice ratio. My framework suggests that the differences in sacrifice ratios may reflect the different impact of the two types of monetary policy changes on macroeconomic welfare, contributing to reconciling the variability in the range of the sacrifice ratio tabulated across these studies. Secondly, persistent changes in endogenous monetary policy have lower repercussions on output and hours, as compared to transitory and surprising changes in monetary policy. This evidence supports the view that to achieve a certain macroeconomic objective, adjusting to a new (unannounced) inflation target is better than unannounced monetary policy changes reflected in discretionary changes in the interest rate, extending the literature on changes in the inflation target (Svensson [2010]).

2.5 Conclusion

In this chapter I decomposed deviations of the Federal funds rate from a Taylor type monetary policy rule into exogenous monetary policy shocks and a time-varying inflation target. In my framework, exogenous changes in the interest rate could be due to changes in a time-varying inflation target causing exogenous monetary policy shocks to be misidentified. This could lead the model to wrongly attribute business cycle fluctuations to exogenous changes in monetary policy, when they are in fact due to changes in the inflation target. My results suggest

that the inclusion of the time-varying inflation target helps further clarify the contribution of exogenous changes in policy. It also plays an important role in contributing to business cycle fluctuations, generating macroeconomic volatility, and has important implications for policy prescriptions.

Using an extrapolated series for the inflation target to estimate a large business cycle model of the U.S. with a stochastic inflation target, explains approximately half of the model-implied volatility associated with monetary policy shocks. It also confirms evidence of a large fall in variance of exogenous monetary policy shocks, compared to a fixed inflation target model. The peak in the variance of exogenous monetary policy shocks occurs during the peak in the variance of the shocks to the inflation target extending the findings in Justiniano and Primiceri [2008], Christiano et al. [2005], Gali [2009] and Smets and Wouters [2007]. The time-varying inflation target points to an important source of changes in monetary policy around the dates identified in Boivin [2005]. Accordingly, I show that that a model with a fixed target overestimates the effects of exogenous monetary policy shocks, which are calculated to have been attributed with excess of 12% volatility in interest rate, 27% volatility in labor hours, 30% volatility in inflation and around 24% additional volatility in output.

This chapter finds that almost 39% of the volatility in inflation may be attributed to the time-varying inflation target during the Great Inflation, suggesting a novel channel to interpret bad monetary policy, extending the findings presented in Clarida et al. [2000], Summers [2005] and Taylor [1999], Primiceri [2005]. My framework suggests that one reason inflation might have been less volatile during the Great Moderation may be due to the time-varying inflation target bounded within a narrow range, supporting the main results presented in Tetlow [2008]. Changes in the inflation target and exogenous shocks to the federal funds rate, are shown to impact the economy differently. To achieve the same macroeconomic objectives, changing the inflation target may suggest a considerably lower sacrifice ratio, compared to transitory perturbations in the interest rate,. It costs 4.5 times

more when using exogenous interest rate changes compared to exogenous inflation target changes, to cause disinflation, contributing to the findings of Fuhrer [1994], Wascher et al. [1999], Ball and Reyes [2007] and Cecchetti and Rich [1999].

A natural extension of this project is to explore the actual causes of the time-varying inflation target, possibly using the FOMC transcripts. Moreover one can allow both the targets and the policy parameters to vary over time, and study the role of each in explaining exogenous policy shocks in a non-linear setting. These are issues to be explored in future work.

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Chapter 3

The Conduct of Monetary Policy: A Review of the Literature

3.1 Introduction

This chapter summarizes and evaluates the literature on the management of monetary policy by the Federal Reserve (the 'Fed') in the U.S. The main fulcrum of economic activity is determined by the setting of the nominal anchor, which is the Federal Funds Rate (FFR) target. The monetary policymaking body of the Fed, the Federal Open Market Committee (FOMC) takes the decision on the FFR target. Following each meeting, the FOMC issues a policy statement that summarizes the Committee's economic outlook and the policy decision (the FFR target) made at that meeting.

The actual conduct of monetary policy could be split into the implementation stage and the decision stage. Firstly, since central banks are suppliers of legal tender, they assert sufficient leverage over the workings of both the real and nominal side of the economy. In principle, commercial banks maintain reserves in the form of cash and deposits at the Central Bank. The Central Bank attempts to control reserves by buying and selling financial securities, for example, Treasury bills in exchange for its own liabilities. However, the exact degree of the adjust-

ment of bank reserves, and consequently the FFR, depends on a central bank's choice of targets. The U.S. Congress, under the Federal Reserve Act, mandates the final targets or goals of the Federal Reserve.

This chapter focuses on decisions about policy rules which explain the behaviour of the FOMC, and therefore focuses on the decision of selecting the FFR target in order to achieve the long run policy goals. For convenience, the only decisions considered for the conduct of monetary policy will be the determination of nominal interest rates. For practical purposes, I assume that it is technically possible to perfectly set this short-term interest rate, at least on a quarterly basis. In this context, one popular categorisation of the behaviour of the FOMC could be an interest rate rule responding to the structure of the economy. Simply put, such a policy rule prescribes how a central bank could adjust its interest rate policy instrument in a systematic manner in response to developments in the macroeconomy, such as in inflation and output.

However, simple policy rules have been criticized on the grounds that they may not capture the complete preference structure of the monetary authority, and therefore may ignore valuable information about the structure of the economy (Mishkin [2007a]). Amongst central banks that have been granted operational independence, a commonly observed mandate is one that specifies an objective to ensure price stability, while avoiding substantial fluctuations in output. In practice, central banks appear from time to time to adopt additional objectives as discussed in Bernanke and Blinder [1992], but as the statement above makes clear, additional objectives entail policy trade-offs. In this regard, there are numerous other indicators, which the central bank studies as informational variables, or as medium term targets, in order to achieve long run goals. In this chapter I summarize the literature on some of these objectives, such as exchange rate and money growth targets. Beyond these simple policy rules, I also summarize the arguments in the literature in favour of alternative targeting procedures such as constant money growth targeting, and nominal GDP targeting. In particular

I explore the merits and demerits of each type of objective or framework, and examine the macroeconomic preconditions of each policy.

Secondly, as has been argued by Taylor and Woodford [1999], policy rules provide a useful framework to compare historical policy and for the econometric evaluation of alternative decisions that a central bank could use to compare possible interest rate trajectories. I explain the performance of these other objectives in the historical conduct of monetary policy, by summarizing empirical evidence that studies the positive performance of these rules based on their actual usage by the Fed. Where actual experimentation by the Fed is missing (for example, it can be argued that nominal GDP targets were never used by the Fed), I rely on normative analysis, and summarize the literature which presents counterfactual outcomes on macroeconomic indicators had the Fed adopted these alternative frameworks. The main result of this exposition suggests that the Fed has over the years adopted multiple policy objectives. These include not only money growth targets and output growth objectives, but also complex rules, which are generally not robust across all models and form one of the main criticisms of these extended rules. In this context, simple rules, such as the one espoused by Taylor [1999] remain the welfare maximising policy choice.

Generally, it has also been argued that a central bank's reaction function may change over time due to evolving policies, preferences and uncertainty about the future. The existing literature has argued in favour of a time-varying parameter model of a monetary policy reaction function to better integrate changing policies and strategies of the Fed, as well as the reactions and decisions over various trade-offs when comparing macroeconomic variables such as inflation, the output gap and the real exchange rate gap. While this may be due to many reasons, such as the changing view of the policy makers regarding the structure of the economy, or to the changing dynamics of the output gap, the rate of unemployment and the exchange rate, it provides a novel insight on the rule versus discretion debate. In light of this, I study whether central banks can always follow a commitment since

these 'rules' are shown to vary over time. This is even more relevant in recent years, where many analysts have pointed to rules that achieve financial stability during periods of turmoil. However, the consensus seems to be that rules may serve as a good benchmark to compare actual macroeconomic performance, and while discretionary policy seems to explain actual policy of the Fed in the post-war period, rule based policy remains a good benchmark to study its normative performance.

This chapter is presented in the following order: section 3.2 presents a summary of the conduct of monetary policy, and in particular focuses on the instruments, targets and objectives of policy. In section 3.3 I review the criticisms of simple policy rules by focusing on the merits of other policy objectives that might help in achieving the monetary authorities long run goals. Section 3.4 studies alternative monetary policy frameworks. Section 3.5 studies the rule versus discretion debate in light of changing objectives and policy rules. Section 3.6 concludes by focusing briefly on some of the other caveats related to policy rules, which are not fully explored in this chapter.

3.2 The Design of Monetary Policy

The monetary authority maintains tight control over certain instruments that influence operating targets and which are used to achieve the final goals or objectives of policy. In this section, I clarify some of the main terms used in this chapter.

The instruments of the central bank, such as bank reserves or the discount rate (Fed [2005], Friedman and Kuttner [2010]), can be categorized as either direct or indirect. Direct instruments function according to regulations and directly affect the interest rate or the volume of credit (Fed [2005], Khan [2003]). The monetary authority can therefore set interest rate ceilings, change reserve requirements or change the discount rate. Indirect instruments such as open-market operations (the purchase and sale of securities, primarily U.S. Treasury securities) and central

bank lending procedures, are used to inject and absorb liquidity, and affect the market-determined price of bank reserves (Khan [2003], Friedman and Kuttner [2010]).

The targets of monetary policy summarize proximate goals, which work directly toward achieving the longer-term objectives of policy. The targets of monetary policy can further be classified either as operating targets or intermediate targets (Friedman [1976], Gambs et al. [1979], Garcia [1984], Friedman [1984], Dueker [1995], Friedman and Kuttner [2010]). Operating targets are goals that the central bank can influence in the short run such as reserve money and short-term interest rates. These operating targets influence movements in intermediate variables, which ultimately affect the final objectives of monetary policy. Intermediate targets have historically been centred around money supply, but bank credit and exchange rates are other intermediate targets used to achieve final policy goals (Khan [2003], Friedman and Kuttner [2010]).

Finally, policy objectives include the final aims or purpose of monetary policy. They have traditionally included price stability, stable growth, maximum employment, stabilising the financial markets and smoothing the real exchange rates (Pierce [1969], Garcia [1984], Dueker [1995], Khan [2003], Friedman and Kuttner [2010]). The goals of monetary policy are described in detail in the Federal Reserve Act, specifically the Employment Act of 1946 and the Full Employment and Balanced Growth Act of 1978. According to Fed [2005] these acts specify that the Board of Governors and the Federal Open Market Committee should seek "to promote effectively the goals of maximum employment and economic growth, stable prices or low inflation, stable financial markets and moderate long-term interest rates."

3.3 What Constitutes a Policy Rule?

3.3.1 Baseline Framework

As history of economic thought makes clear, stable monetary policy avoids generating monetary policy surprises (or shocks), and protects the economy from unfavourable disturbances, thereby reducing the chances of exacerbating a recession, causing a depression or an economic crisis, or experiencing large deflations or hyperinflations (Taylor and Williams [2010]). It has also been proposed that simple policy rules prevent monetary excesses, whether related to money finance of deficits, commodity discoveries, gold outflow or mistakes by central banks with conflicting goals, making price stability easier to achieve.

The first issue that is commonly addressed in the literature is the (aptly named) classic instrument problem, which attempts to explain whether the monetary authority should seek to control the quantity of reserves or the price of reserves. However, Poole [1970] points out that a price (interest rate) rule performs better as compared to a quantity (money supply) instrument under the standard model of the U.S economy. In this context, I shall be concerned with the reaction function that considers interest rates to be the sole instrument of policy. In practise, however, the Fed's operating procedure has evolved in the past five decades. However, Bernanke and Blinder [1992] and Bernanke and Mihov [1998] suggest that the Fed funds rate has been the main policy instrument in the United State over most of that period.

The decision about the Fed funds rate could be described as an interest rate rule that responds to the structure of the economy. Policy rules have been used to compare central bank strategies and to study alternate approaches to interest rate decisions. A generic reaction function considered by Christiano et al. [1999] takes the following functional form:

$$S_t = f(-_t) + \sigma_s \epsilon_t^s \tag{3.1}$$

Here S_t is the main instrument of the central bank, say the federal funds rate, and f is a linear function that relates S_t to the information set $-_t$. The random variable, $\sigma_s \epsilon_t^s$ is the monetary policy shock. The term, ϵ_t^s is normalized to be mean zero and unit variance, with σ_s often referred to as the standard deviation of the monetary policy shock. A popular interpretation of f and $-_t$ is that they represent the monetary authority's feedback rule and information set, respectively. For example, Taylor [1999] has argued that a rule explaining the behaviour of the Fed from 1987 - 1992 could be written as:

$$i_t = \pi_t + r_t^* + \phi_\pi(\pi_t - \pi_t^*) + \phi_y(y_t - \bar{y}_t) \tag{3.2}$$

In this case, Taylor's rule prescribed that the Fed funds rate i_t should respond to fluctuations in actual inflation (π_t) rates from target inflation rates (π_t^*) and of real Gross Domestic Product (GDP) growth (y_t) from potential GDP ($\bar{y}_t$). The mechanism behind this rule is simple: when inflation rises above its mandated long run target, monetary policy should aim to raise its nominal interest rate which would decelerate the economy and reduce inflationary pressures. Furthermore, Taylor [1993] proposed that both ϕ_π and ϕ_y should be set to 0.5. This policy rule suggests that monetary policy reacts by increasing the interest rate by a particular amount when real GDP or inflation rises above potential GDP or the inflation target, and reduces the interest rate symmetrically when real GDP or inflation falls below potential GDP or the inflation target (that is, 'leans against the wind'). By systematically setting interest rates, this rule stabilizes the economy close to the long run policy goal and also protects it from large shocks in the interest rate, which can be welfare-reducing.

Various functional forms for this policy rule have been considered in the literature. For example, Clarida et al. [2000] propose augmenting this rule with policy inertia by including lags for the Fed funds rate based on evidence of short-run smoothing of rates by central banks. However, beyond the fundamental functional form of the basic policy rule, simple monetary policies have been criticized

for being too simple, since they are not subject to the transmission mechanism, and may therefore not be tailored to cope with its specific structure. In the words of Svensson [2003] and Mishkin [2007a] these rules may be too simple to explain the behaviour of interest rates in the real world. Other variables, such as broad money growth, might display reliable relationships with longer-term goals such as inflation, and therefore be used by the central bank as if an objective of policy. Alternatively, output growth might be easier to measure in real-time (see, for example, Walsh [2003b], Orphanides [2004] and Orphanides and Williams [2006]), and therefore may enter the reaction function. Accordingly, pursuing these other objectives either combined with a simple Taylor rule or otherwise, might improve attaining the twin goals of price stability, maximum employment and economic growth.

In this sense, the existing literature has focused on the merits of using these variables as objectives of policy. I next focus on issues concerning some of these variables, and summarize the literature on the historical consequences of their use by the FOMC.

3.3.2 Intermediate Targets

In general, a central bank normally decides on intermediate targets or guiding variables in order to attain long term goals, and which therefore serve as a link between operating variables and goal variables (Friedman [1976], Friedman [1984], Dueker [1995], Friedman and Kuttner [2010]). It has been argued that intermediate targets ideally possess four properties. First, the central bank should be able to closely control them so that policy makers know where to set the policy instrument in order to obtain the desired change in the intermediate target (Dueker [1995]). Second, an intermediate target should have a predictable and stable relationship with long run goals of monetary policy (Dueker [1995], Mishkin [2007b]). Third, they should be an accurate leading indicator of final targets (Garcia [1984]). Fourth, its data should be accurate and timely (Garcia [1984]).

I evaluate the merit and demerits of some intermediate targets, and discuss the Fed's historical experience with these variables.

Monetary Aggregates

The evolution of central banking in the 1950s and 1960s generated support for the idea that the monetary authority needed to control the growth rate of monetary aggregates (of New York [1990], Mishkin [2007b]).[1] This formed the basis for the adoption of monetary targeting by a number of industrialized countries in the mid-1970s. According to Friedman et al. [1996] since money growth does not comove precisely with these indicators of macroeconomic performance, if the mandate of the monetary authority is price stability (of New York [1990], Belongia and Batten [1992]), then an obvious candidate for the intermediate target is monetary aggregates. In this sense aggregates may be used as information variables for the conduct of monetary policy, as discussed in Estrella and Mishkin [1997], Mishkin [2007b], and which can be used to enhance a central banks credibility (Estrella and Mishkin [1997]). However, there is a difference between a monetary policy that responds only to movements of prices and real activity and a monetary policy that, at least in part, targets money growth. I explore consequences of the latter type of policy in this section.

Monetary targeting involves the reliability of information conveyed by a monetary aggregate to conduct monetary policy (Friedman [1984], of New York [1990], Dueker [1995], Mishkin [2007b]), and the announcement of medium-term or medium to long term targets for monetary aggregates (Mishkin [2007b]). The intuition behind announcing monetary aggregates in the medium term rests on signalling to both the public and markets about the stance of monetary policy and the objectives of the policymakers to keep inflation in control. In theory, these signals can help fix inflation expectations and produce less inflation. Last,

[1] For the purposes of this discussion, I will categorize as monetary aggregates M1, M2, M3, monetary base. Garcia [1984] contains a detailed account on the individual merits of these indicators.

monetary targeting requires an accountability framework to prevent fluctuations from the monetary targets (Mishkin [2007b]). This enhances a central bank's credibility by promoting almost immediate accountability for monetary policy in order to keep inflation low.

The advantages of monetary aggregate targeting rest on a strong and reliable relationship between the goal variable (inflation or nominal income) and the targeted aggregate (of New York [1990], Mishkin [2007b]. This can be a double edged-sword since large swings in velocity in money demand produce an undesirable equilibrium outcome on the goal variable. In this sense, the monetary aggregate being used as an intermediate target will no longer provide an adequate signal about the central bank's policy stance.

There may be other potential issues with using monetary aggregates as intermediate targets of policy. First, the problem of which measure of money to target, as different authors have espoused M1, M2 M3 and even the monetary base as appropriate indicators to target, with each measure of money leading to a different set of pros and cons (Garcia [1984]). Second, structural changes, especially financial innovation - such as the growing use of credit cards - has diminished the relationship between M1 and GNP (Garcia [1984], of New York [1990], Mishkin [2007b]), leading to problems related to the definition of money, and issues related to the appropriate monetary aggregate to target.

Conclusions based on the empirical evidence of their performance in practise remain uncontroversial. Friedman et al. [1996] and Friedman [1984] present some evidence of money growth targeting in an interest rate framework, and conclude with positive evidence in favour of money growth targeting especially during the last years of the 1970s and early 1980s. Mishkin [2007b] discuss monetary aggregate targeting in detail in the 1970s and early 1980s and conclude that central bank policy was not transparent, as it did not prevent the monetary base from drifting ("base drift"), and large unsystematic changes in targets or target growth rates. Moreover, they point out that successfully using money targets requires a

strong commitment by the monetary authority, which would need to reverse previous fluctuations in the target in order to keep the long run target close to the initial objectives. The results by Meulendyke [1988], Goodfriend [2005], Larkin et al. [1988] and Mishkin [2007b] back this claim. Lastly, Sims and Zha [2006] provide strong evidence of money growth serving as an important indicator variable. In particular their empirical findings are suggestive of the pre-Greenspan era as a time when the Federal Reserve focused on money more so than interest rates.

Exchange Rates

The groundbreaking developments in economic theory, and the global experience with the high inflation of the 1970s, led to a growing recognition of the high costs of inflation. According to Mishkin [2007b], this issue made clear why a nominal anchor is crucial for stability in prices. Moreover, the apparent deterioration of conventional monetary policy guides spurred discussion of dollar exchange rates as possible intermediate targets of policy. Little, in contrast, has been written about the use of exchange rates as targets or indicators in a domestically oriented monetary policy of the sort used in the United States, as discussed in of New York [1990].

Particularly, when discussing exchange rates as intermediate targets, the issues that must be considered include not only those discussed in the standard literature on domestic targets and indicators, such as the 'stability' of a variable's relation to the operating targets and goal variables and the information content of potential indicators (Dominguez [1992]), but also those arising from the special characteristics of exchange rates as macroeconomic variables and the operations behind exchange rate management as discussed in Girton et al. [1976]. The foremost, and certainly most obvious, feature distinguishing exchange rates from more traditional monetary policy tools is their international character (of New York [1990]). Admittedly, domestic interest rates and other conditions are increasingly influenced by conditions abroad, but dollar exchange rates are inherently inter-

national variables in that they are determined by foreign as much as domestic conditions. Plainly, the U.S. monetary policy cannot independently target dollar exchange rates (Girton et al. [1976], of New York [1990]), Carte et al. [1992], Williamson [1993]), but can use them as informational variables to guide policy makers.

According to Williamson [1993] exchange rate targets rely on the 'stability' of the exchange rate with the final policy goals, and on the degree of international monetary policy coordination[2]. They require a thorough knowledge of the determinants of movements in exchange rates, which in principle are influenced by determinants of domestic and foreign interest rates, home and foreign price levels, and the relative price of traded and non traded products Feldstein [1989]. Moreover, the interaction of exchange rates with interest rates, prices and incomes is likely to be complex, and the pattern of these interactions depends critically upon the formation of expectations (of New York [1990]).

In this regard, the literature has reached some conclusions about exchange rate targets, though empirical examples seem to be limited. The first is that the use of exchange rates in monetary policy raises broader issues than those associated with the use of more traditional domestic target variables such as the money aggregates and interest rates. The dynamics of exchange rates are significantly more varied than those affecting domestic interest rates and other traditional monetary policy variables, and the present understanding is considerably limited (of New York [1990]). Equally important, the systematic use of exchange rates in U.S. monetary policy formulation would almost inevitably involve considerations of international economic policy interdependence to a much greater degree than does the use of interest rates or other more obviously domestic variables.

Secondly, the use of exchange rates as primary intermediate targets of U.S. monetary policy, even if those targets are fairly flexible, would not improve the performance of policy in maintaining macroeconomic stability, and could easily

[2]For example, developments in the dollar have important impacts on the income, price levels, and trade balances of the trade partners of the U.S.

add to instability under the circumstances that prevailed through much of the last decade (of New York [1990]). Moreover, the use of exchange rate targets would be most appropriate if shifts in the demand for money balances were the primary macroeconomic disturbances to currency values and the economy at large, a proposition very strongly rejected by both the literature and historical experience. However, according to Mishkin [2007b], the key objective during the 1980s was stabilising the exchange rate. According to their analysis, the rapid appreciation of the dollar during the Volcker regime led to a massive increase in the U.S. current account deficit. By increasing both M1 and M2 growth rates, they propose that the Fed attempted to bring down the dollar. This is also the conclusion reached by Furlong [1989].

Finally, neither should the current U.S. monetary policy be significantly modified to take a more systematic account of exchange rates, nor should exchange rates be ignored by policy. The two most important approaches in this context are the ad hoc use of exchange rate considerations as policy guides foreign exchange markets affect local conditions, and the use of exchange rates as indicators of the state of the economy and the policy stance. The difficulty is that present knowledge is inadequate to define how policy makers might more reliably and systematically use such exchange rate considerations.

3.3.3 Other Objectives

Output Growth

Walsh [2003b], Orphanides [2004], Orphanides and Williams [2006] and Coibion and Gorodnichenko [2011] have discussed the merits of output growth targeting as an objective that monetary policymakers can respond to for stabilization purposes. Their framework rests on the argument by Woodford [1999], who calls for inertia in policymakers' response to inefficient fluctuations in a world with forward looking expectations. By introducing inertia into policy actions, the central bank's current actions affect the public's expectations of future inflation. Walsh [2003b] suggests

that when a central bank strives to stabilize the change in output gap, lagged output gap becomes an endogenous state variable which, even under discretion, introduces inertia into policy. The use of output growth as a policy objective rests on the principle that in a forward-looking model, such a policy would induce history-dependence.

Second, Coibion and Gorodnichenko [2011] have suggested that responding to output gap growth affects the price equilibrium determinacy properties in a New Keynesian model with trend inflation, and responding to expected output growth amplifies the central bank's response to inflation. Theoretically, they show that strong responses to output growth helps restoring determinacy, whereas strong responses to the output gap can be destabilizing for the price level. In light of these findings they conclude that a positive response to the real side of the economy should not necessarily be interpreted as central bankers being "dovish" on inflation since it helps stabilize the price level. Giannoni [2001] has suggested that the optimal central bank response in standard models also contains an objective for output gap growth, and therefore lends theoretical grounds to both Walsh [2003b] and Svensson [2000].

Empirically, measurement error in output gap has been shown to be critical for policy implementation and the historical policy mistakes, especially those that occurred before the Great Moderation. Orphanides [2003] has argued that mismeasurement in output gap contributed to the excessive inflation of the 1970s as policy makers systematically over estimated the output gap. In this sense, the growth rate of potential output is measured more accurately than its level, and first differencing the log level of the estimated gap reduces the variance of the measurement error. Coibion and Gorodnichenko [2011] show that since the appointment of Chairman Volcker, the Fed has been responding strongly to output growth. Interestingly, if the FOMC were to stop responding to both the output gap and output growth, there would have been periods of indeterminacy even during the Great Moderation according to their findings.

Financial Stability

The global financial crisis of 2007-9 has led to a reassessment of the scope of monetary policy, as well as to substantial reforms of the framework surrounding the regulation of financial institutions. In particular, new macro prudential tools have been introduced in many jurisdictions, and in some instances placed under the authority of the central bank (Hanson et al. [2010]). However, macro prudential tools remain untested, and their effects are highly uncertain. Furthermore, their scope is by nature limited to the regulated segment of the financial system, creating problems of policy 'leakages' between regulated and unregulated entities, and between domestic and foreign institutions (see, for example, Aiyar et al. [2014], Pozsar et al. [2010]). According to Stein [2013], conventional monetary policy is flexible, and therefore affects the financial system beyond targeted regulatory tools.

The merits of directing monetary policy towards stabilizing financial variables, in particular stock market booms, has attracted a multifaceted view. According to one view, financial stability could best be achieved by ensuring price stability. Bernanke and Gertler [2000] argue that these objectives could be seen as complementary, and could therefore be achieved by adopting a flexible inflation target. From a practical perspective, spotting asset price misalignments may be hard and booming asset prices would show up as higher spending and inflation, thereby rejecting the need for a direct policy response. Another view suggests that central banks should have regard for financial factors as such, when setting monetary policy. This is often referred to as 'leaning against the wind' (see, for example, Bean [2003]). While not rejecting the effect of asset price booms on demand and inflation, this perspective has warned that in the event of a sudden reversal in asset prices, 'mopping up' through looser policy created an asymmetry that could itself feed asset booms.

Several papers have analysed optimal simple monetary rules to understand whether, in economies subject to financial frictions, policymakers should respond

in a systematic way to financial factors when their aim is to either maximize social welfare or to minimize an ad hoc loss function, which reflects the central bank's mandate. Curdia and Woodford [2010] find that while a Taylor rule augmented with variations in credit spreads can improve upon the standard Taylor rule, a response to the quantity of credit is less likely to be helpful. Gambacorta and Signoretti [2014] find that a Taylor rule augmented with asset prices and credit can improve welfare as compared to a standard Taylor rule. Gelain and Ilbas [2014] study optimal simple monetary and macro prudential rules in a version of the Gertler and Karadi [2011] model estimated on U.S. data. Their paper considers the gains that might be achieved from setting policy instruments in a coordinated manner.

The issue of using monetary policy for financial stability purposes is hotly contested. The financial crisis was a reminder that price stability is not sufficient to ensure financial stability, that financial crises are costly, and therefore policy should aim to decrease the likelihood of crises and not just rely on dealing with their repercussions once they occur. It is clear that well-targeted prudential policies (including micro and macro prudential regulation and supervision) should be pursued to attenuate the build-up of financial risks. However, the question of whether monetary policy should be altered to contain financial stability risks remains unanswered.

3.4 Alternative Frameworks

3.4.1 Constant Money Growth

Originally espoused by Friedman [1948], constant money growth implies increasing the money supply by a constant number, say 2%, irrespective of business cycles. The central idea is simple enough, for Friedman suggested that 'inflation was everywhere a monetary phenomenon' so controlling the supply of money would rein in inflation. Tight control over the growth of money supply meant that the cycli-

cal properties of the business cycle would be tamed as well. This would serve as a corrective mechanism during inflation and booms (or the opposite). Further merits of such a framework also discuss the possibility of lags in policy, implementation, and information acquisition. Under such lags, policy implementation made choosing the correct supply of money for each period difficult, so fixing it to some long run potential meant eliminating lags in policy. A policy maker also faces uncertainty about the true model; for example, a popular debate during this time was about the nature of prices in the economy, and whether the policymaker should factor in rigid prices or flexible prices. Friedman [1948] shows such uncertainty about the nature of the structural mechanism, or a limited understanding of the transmission mechanism supported such a simple policy rule.

Firstly, this policy rule is based on the equation of exchange. Using the notation presented in Orphanides [2007], one can express this in growth rates:

$$\Delta m + \Delta v = \pi + \Delta q \tag{3.3}$$

In this equation $\Delta p = \pi$ represents inflation, and where p, m, v and q are logarithms of the price level, money stock, money velocity and real output, respectively. By appropriately accounting for trends in the velocity of money Δv^*, and by setting the constant growth rate of money, k, to equal to the sum of desired inflation π^* and the economy's potential growth rate, Δq^*, Orphanides [2007] suggests a simple rule can achieve on average the desired inflation target, π^*:

$$\Delta m^* = \pi^* + \Delta q^* - \Delta v^* \tag{3.4}$$

Secondly, if the velocity of money is fairly stable (Δv^*) this simple rule would also yield a high degree of economic stability through the mechanism of stable prices. During the 1960s and 1970s, Friedman recommended that the Federal Reserve fix the rate of money growth to 4 percent per year. His suggestion was based on the premise that potential output in the U.S. is roughly 4 percent.

Surprisingly, only a few papers have discussed the determinacy properties of these rules. Keating et al. [2014] show (analytically) that Friedman's k-percent rule can deliver a unique rational expectations equilibrium when the true monetary aggregate is used. They also study the merits of using the right measure of money to achieve determinacy, which may be affected by the policymaker using the wrong money aggregate. Evans and Honkapohja [2003b] analyse determinacy properties of these so called k-percent rules in a New-Keynesian model when money is modelled as a single monetary asset. They show numerically that fixing the growth rate of this measure of money is consistent with unique rational expectations equilibrium under a broad range of values.

Empirical evidence of the performance of these rules is fairly limited to the choice of model, and the sort of issue contextualized within a policy framework. In most of the existing literature, this policy rule serves as a reasonable benchmark to compare alternative policy formulations. For example, Kilponen and Leitemo [2008] show that with plausible degree of model uncertainty, delegation of the Friedman rule of increasing the money stock by a constant percentage to the central bank tends to outperform commitment to the social loss function (that is, flexible inflation targeting). Their reasoning is based on a welfare-based analysis, which suggests that the inefficiency of money growth targeting is smaller compared to the price paid for robustness under flexible inflation targeting. In their framework, having an imperfect control over changes in money does not change this conclusion. Gali [2009] shows that in the absence of money demand shocks, such a policy rule dominates a standard a Taylor formulation in welfare terms. This result is over-turned in the presence of money demand shocks.

3.4.2 Targeting Nominal GDP

The search for a robust indicator, and the fall in reliability of monetary aggregates for the conduct of monetary policy, has also increased interest in identifying other potential guidelines for setting the nominal interest rate. A popular stream of lit-

erature has emerged, especially in recent years, which argues in favour of targeting nominal gross domestic product (GDP). In principle, this type of rule recommends the appropriate path for the nominal interest rate in response to divergences of nominal GDP from its long run target. According to Orphanides [2002] a potential advantage of nominal GDP targeting over output gap targeting is that the former is easily observed, whereas the output gap is based on a hypothetical model construct that is probably difficult to observe even ex-post, much less in real time. It has therefore been argued that a nominal GDP target is probably also far easier to communicate to the public than a gap-targeting rule.

Using the notation described in the previous section the growth of nominal income can be defined as the sum of the potential growth rate of output and the central bank's inflation target, and therefore can be expressed as $\Delta x = \pi + \Delta q$. Therefore, a rule for constant money growth can be seen as targeting the natural growth rate, $\Delta m = \Delta x$. According to Orphanides [2007], this rule requires minimum information for implementation, is stable across alternative models of the economy, and therefore is robust to possible model misspecification. For example, Cooper and Fischer [1972] show that improved macroeconomic performance could be achieved by modifying this rule to allow some automatic response of money growth to economic developments. Mccallum [1988] and McCallum [1993] have proposed an alternative simple rule, following Cooper and Fischer [1972]:

$$\Delta m = \Delta x^* - \Delta v^* - \phi_{\Delta x}(\Delta x - \Delta v) \tag{3.5}$$

According to Sumner [2014], the mechanics of such rules are simple. Given a state where the long-run trend rate of growth in the economy is 3 percent, then a nominal GDP growth target of 5 percent will deliver the same outcome as long-run rates of inflation at a 2 percent inflation target. This has an added advantage of being flexible since it keeps the nominal GDP robust to any chosen rate of inflation or deflation. Theoretically, this type of regime responds to demand shocks (or changes in velocity) in exactly the same way as an inflation-targeting regime.

The only difference arises when the monetary authority faces a trade-off between inflation and output growth, such as what would occur in the face of exogenous increases in oil prices. In a recent paper, Garín et al. [2016] investigate the determinacy properties of gap targeting when trend inflation is positive. They find that if trend inflation is greater than about 0.2 percent annually, then gap targeting results in equilibrium indeterminacy. Because in the long run the level of output is independent of monetary policy, nominal GDP targeting is equivalent to a price level target in the long run, and therefore supports a determinate equilibrium for any level of trend inflation. Second, in terms of estimating whether the US has been an implicit nominal income targeter, the authors estimate the parameters of this model via Bayesian maximum likelihood.

Empirically, McCallum [1993] showed that had such a rule been followed during the 1930s and 1970s, the performance of the U.S. economy would have been considerably better than actual performance. Beckworth and Hendrickson [n.d.] show that a rule where the nominal interest rate is a linear function of nominal GDP growth outperforms the conventional Taylor rule when real time forecasts are used for the output gap. They study nominal GDP targeting in a framework that accounts for the real-time knowledge of the output gap and assume that the central bank has to forecast the output gap using lagged information. Taylor [1985] examines economic performance with nominal GNP/GDP targeting, emphasizing the difficulties caused by the lagged responses of output and prices to previous policy. Garín et al. [2016] also evaluate the welfare properties of nominal GDP and show that nominal GDP targeting is associated with smaller welfare losses than a Taylor rule. They also show that this policy rule significantly outperforms simple inflation targeting rules.

To conclude, a rule that targets nominal GDP dominates inflation targeting in welfare terms, conditional on the supply shocks and when wages are more sticky relative to prices. Moreover, nominal GDP targeting may outperform output gap targeting if this gap is observed with noise, and has more suitable characteristics

related to equilibrium determinacy than does output gap targeting as discussed in Orphanides [2002].

3.5 Issues in Rules and Discretion

Dynamic, stochastic, and empirically estimated models, encompassing rational expectations and price stickiness emerged in the 1970s and were sophisticated enough to examine the welfare implications of different monetary policy rules.[3] Although there was some disagreement about which type of rule central banks should follow, economists agreed that rule based policy is preferred to discretionary policy. In the words of Taylor and Williams [2010], the choice has always been between 'rules versus chaotic monetary policy, whether the chaos is caused by discretion or unpredictable exogenous events like gold discoveries or shortages'. Second, the concept of dynamic inconsistency by Kydland and Prescott [1977] revolutionized this strand of literature.[4] Third, the performance of the Federal Reserve during the Great Inflation of the 1970s, and the subsequent Great Moderation, supported rule-based policy as discussed in Taylor and Williams [2010].

Research then focused on using optimal control theory to study more complex monetary policy actions, such as in Woodford [2011], and compared their performance to simple rules. In light of this approach Mishkin [2007a] computed paths for the Federal Funds Rate and contrasted the welfare implications with simple policy rules. He found that the "Federal funds Rate is lowered more aggressively and substantially faster than with the Taylor rule...This difference is exactly what we would expect because monetary authority would not wait to react until output had already fallen". The implied proposition is that simple pol-

[3]Examples of these models include Taylor [1979], which is further evaluated in Bryant et al. [1993].

[4]The application to the rules versus discretion debate originates from the claim that policy will be dynamically consistent if it is based on rules. By contrast, a government or central bank with discretionary powers may, under rational expectations, be expected to make the short-run optimal decision every time it can, therefore gains nothing from its opportunism. This type of policy, therefore, produces a worse equilibrium outcome than would a government able to tie its hands, and focus on rule based approaches to policy.

icy rules are incompetent for real-world situations and that policymakers should diverge from them when the need arises. However, how can the monetary authority tie up rule-based policy and keep up with the new challenges posed by the macroeconomy? I elaborate some issues.

First, the discussion centres on the purpose for which these rules are being estimated and utilized. On one hand the proponents of rule based policy, such as Taylor and Woodford [1999], find rules to be robust across different models, beyond what may be econometrically deciphered from the actual decisions of the monetary authority. McCallum [1999] focuses on the positive nature of the decisions of the central bank. One can immediately infer from this debate that a simple rule, such as the one espoused by Taylor [1999] serves as a reasonable benchmark to compare alternative policy rules, but is rarely practised by the central bank. According to Fischer [1988], one of the most important arguments for discretionary policy is that it leaves the policymaker the flexibility to respond rapidly to contingencies not foreseen nor describable in the potential rule.

The second issue stems from the first, and delves deeper into the philosophy of rule-based policy. It is not clear whether rule based policy implies committing to policy objectives such as inflation and the output gap, or a commitment to both objectives and its preferences. In light of the classic definition of rule based policy, committing to a complete policy rule, that is, to all objectives, instruments as well as the preferences of the central bank, would be defined as a rule-based policy. If that is so, similar criticism applied to rule-based policy can be applied to other features of policy making such as selecting policy targets, such as targets for inflation and the right measure of the output gap (which certainly varies over the long-horizon). Both historical estimates of policy rules by Clarida et al. [2000], as well as time-varying estimates of policy rules based on real-time data available to the Federal Open Market Committee (FOMC) by Boivin [2005], Kim et al. [2006] and Coibion and Gorodnichenko [2011] suggest that preferences towards objectives vary over time. This would add to the complication of selecting a policy rule which

were to last for all times.

Third, given the nature of economic crises, local or international conditions beyond the central banks' control, cannot be ignored. In this sense, committing to a rule, which might not produce the most welfare maximising result, would not be the optimal strategy. This argument is in line with Fischer [1988], who argues that it is difficult to attach a large weight to a policy rule if it delivers a weak outcome, and fails to meet the goals of the monetary authority. Therefore, central banks may have to adjust their objectives, or their preferences towards these objectives, based on their understanding of current macroeconomic conditions. This can be further highlighted by empirical evidence that suggests that the classic Taylor rule does not explain the behaviour of the Fed in the Great Recession, where interest rates had been lowered to zero.[5]

To conclude, while discretionary policy seems to explain actual policy of the Fed in the post-war period, rule based policy remains a good benchmark to study its normative performance. It has been argued that simple policy rules have strengths and weaknesses relative to optimal adaptable rationally designed plans, and in this sense serve as a reference point for policymakers when discussing various policy situations. In general, it has been proposed that the central bank with its research should aim to develop a simple rule that reflects the present state of knowledge (and ignorance), and which is robust to error. The central bank should also plan periodic reviews and adaptation of the rule it develops. The main idea behind this approach is to eschew discretion in favour of a transparent, an easy to monitor strategy, which is communicated often to the public.

3.6 Conclusion

The study of rule-based policy offers a simple framework to summarize the arguments in favour of different objectives as part of the policy rule, and their perfor-

[5]See comments by Ben Bernanke: http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/28-taylor-rule-monetary-policy

mance, whether taken in a historical context or whether studied in a model setting. However, there are numerous other issues concerning the conduct monetary policy that affect the establishment of a policy rule.

First, the debate about the timing of targeting variables is unresolved. For example, Svensson and Woodford [2004] argued that the monetary authority should set policy such that its forecast for the macroeconomy is equal to the mandated goal. However, Coibion and Gorodnichenko [2011] have argued that a mixed policy rule, that is, a policy rule where the FOMC targets both contemporaneous and forward looking data on a particular variable better fits the actual policy practised by the FOMC.

Second, an important question that remains to be persuasively answered concerns the right measures of the variable that should be targeted by the central bank. In this context, Taylor [1999] measures inflation using a price index known as the GDP deflator, while customarily, the FOMC has favoured the rate of change in consumer prices, as revealed by the deflator for personal consumption expenditures (PCE). The FOMC certainly targets overall PCE inflation, but has typically viewed core PCE inflation (which excludes volatile food and energy prices) as a better measure of the medium-term inflation trend and thus as a better predictor of future inflation.[6]

Third, policy inertia introduced by the monetary authority when setting interest rates is another important facet of the conduct of policy and is not addressed by simple rules. Giannoni [2007] has shown that a loss function minimising central bank adjusts the nominal interest rate with considerable inertia. This has been shown by Rotemberg and Woodford [1999] to be a desirable feature in their econometric model with optimizing agents. Furthermore, as elaborated by Woodford [2011] this type of 'super-inertia' in policy actions encourages the central bank to optimally respond to shocks when economic agents are forward-looking.

Finally, according to Orphanides [2007], the measurement of natural rates

[6]See comments by Ben Bernanke: http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/28-taylor-rule-monetary-policy

such as the natural rates of employment, output and interest remain a challenging issue in the conduct of policy. While the instrument of policy has been taken as the interest rate, this was adopted merely because the alternative (money growth targets) did not yield the desired outcomes. In this context, the theoretical underpinnings of appropriate instruments need to be further investigated. Inspired by the work of Poole [1970], there is little existing work defending the theoretical restrictions which imply that this instrument is superior to any other. As shown in Gavin et al. [2004], the monetary instrument matters significantly for welfare outcomes. These issues matter critically for the conduct of monetary policy.

Appendix A

Monetarism, Indeterminacy and the Great Inflation

A.1 Robustness

Table 1: NLS/IV estimates

	NLS		IV	
Parameter	(1)	(2)	(1)	(2)
ψ_π	0.75^{**}	0.74^{**}	**0.64**	**0.60**
	(0.27)	(0.27)	(**0.37**)	(**0.39**)
ψ_x	0.38^{**}	0.36^{*}	$\mathbf{0.3}^{*}$	$\mathbf{0.27}^{*}$
	(0.13)	(0.12)	(**0.13**)	(**0.12**)
$\psi_{\Delta m}$	–	-0.03	-0.22	**-0.55**
	–	(0.02)	(0.20)	(**0.53**)
ρ_1	1.03^{***}	1.02^{***}	1.03^{***}	1.04^{***}
	(0.16)	(0.16)	(0.16)	(0.15)
ρ_2	-0.17	-0.17	-0.18	-0.18
	(0.16)	(0.16)	(0.15)	(0.15)
$d_{2,t}$	0.52	0.59	0.51	0.43
	(0.32)	(0.32)	(0.25)	(0.25)
$\rho_1 + \rho_2$	0.87	0.87	0.88	0.88
$p - value$	–	–	0.12	0.18

This table presents NLS and IV estimates of the baseline feedback rule. Standard errors are reported in parenthesis. The set of instruments are lags of inflation, output gap, the federal funds rate and growth in monetary aggregate M1. The bold letters are the instrumented variables. The bottom panel reports the p-value associated with a test of the models over identifying restrictions (Hausman). For the baseline version, I include a time dummy for the 1979- 1982 period. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ denote significance levels.

Table 2: NLS/IV estimates

The time-varying estimates of the policy rule suggest that the Fed targeted money supply from 1970 - 1974, and 1979 - 1987. In order to capture these shifts, I use the exact time period implied by the TV estimates and test for changes using dummies, as also used by Boivin [2005]. My estimated rule then becomes:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1-\rho_{1,t}-\rho_{2,t})[(\psi_{\pi,t}+d_{1,t})\pi_t + (\psi_{x,t}+d_{1,t})x_t + (\psi_{m,t}+d_{1,t})\Delta m_t^n] + c_t + \epsilon_t \tag{A.1}$$

$$d_{1,t} = \begin{cases} 1 & 1970-1974, 1979-1981 \\ 0 & otherwise \end{cases}$$

	NLS		IV	
Parameter	(1)	(2)	(1)	(2)
ψ_π	0.73^{**}	0.37^{**}	**0.46**	**0.50***
	(0.24)	(0.15)	(**0.25**)	(**0.24**)
ψ_x	0.23^{**}	0.33^{***}	**0.13**	**0.39***
	(0.10)	(0.08)	(**0.09**)	(**0.15**)
$\psi_{\Delta m}$	–	0.03	–	**1.06**
	–	(0.03)	–	(**0.72**)
$d_{1,t}\psi_{\Delta m}$	–	-0.17^{**}	–	**−1.36***
	–	(0.05)	–	(**0.67**)
$d_{1,t}\psi_\pi$	0.67	1.03^{*}	**0.41**	**1.09***
	(0.51)	(0.41)	(**0.41**)	(**0.55**)
$d_{1,t}\psi_x$	0.51	−0.001	**0.28**	**−0.32**
	(0.43)	(0.32)	(**0.35**)	(**0.44**)
ρ_1	1.02^{***}	0.97^{***}	1.04^{***}	1.00^{***}
	(0.17)	(0.17)	(0.17)	(0.17)
ρ_2	−0.14	−0.14	−0.15	−0.17
	(0.17)	(0.16)	(0.16)	(0.16)
$\rho_1 + \rho_2$	0.88	0.87	0.88	0.83
$p - value$	–	–	0.22	0.21

This table presents NLS and IV estimates of the baseline feedback rule. Standard errors are reported in parenthesis. The set of instruments are lags of inflation, output gap, the federal funds rate and growth in monetary aggregate M1. The bold letters are the instrumented variables. The bottom panel reports the p-value associated with a test of the models over identifying restrictions (Hausman). For the baseline version, I include a time dummy for the 1979- 1982 period. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ denote significance levels.

A.2 Proof of Determinacy Conditions

Proof of proposition 1. I consider the contemporaneous version of the policy rule presented in the section, and find the determinacy condition of the policy rule with money growth. The model is summarized by the following equations:

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) + g_t \tag{A.2}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \tag{A.3}$$

$$\Delta m_t = \eta_\pi \pi_t + \eta_x \Delta x_t - \eta_i \Delta i_t + \eta_x \Delta y_t^n + \tau_t \tag{A.4}$$

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1 - \rho_1 - \rho_2)[\psi_\pi \pi_t + \psi_x x_t + \psi_m \Delta m_t^n] + c_t + \epsilon_t \tag{A.5}$$

mdgia First, by substituting the money demand equation in the monetary policy rule, I simplify the monetary policy rule:

$$i_t = \delta_1 i_{t-1} + \delta_2 i_{t-2} + \delta_3 \pi_t + \delta_4 x_t + \delta_5 x_{t-1} \tag{A.6}$$

where:

$$\delta_1 = \frac{\rho_1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)}{1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)} \qquad \delta_2 = \frac{\rho_2}{1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)}$$
$$\delta_3 = \frac{(1 - \rho_1 - \rho_2)(\psi_\pi + \eta_\pi \psi_{\Delta m})}{1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)} \qquad \delta_4 = \frac{(\eta_x \psi_{\Delta m} + \psi_x)(1 - \rho_1 - \rho_2)}{1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)}$$
$$\delta_5 = -\frac{\eta_x \psi_{\Delta m}(1 - \rho_1 - \rho_2)}{1 + \eta_i \psi_{\Delta m}(1 - \rho_1 - \rho_2)}$$

Next, I write the model in the following compact state space form:

$$\mathbf{A} z_{t+1} = \mathbf{B} z_t + \mathbf{C} v_t \tag{A.7}$$

and the matrices **A**,**B** are composed of structural parameters, and monetary policy parameters, and **C** is a matrix of exogenous variables. The vector z_{t+1} is composed of the variables $[x_{t+1}, \pi_{t+1}, x_t, i_t, i_{t-1}]$ which contains two non-predetermined

variables and three predetermined variables. Thus, if two of the generalized eigenvalues lie outside the unit circle, then the system has a unique solution (proposition 1 in Blanchard and Kahn [1980]). Alternately, rational expectations equilibrium is determinate if and only if three of the eigenvalues are inside the unit circle. The characteristic polynomial is given by $p(\lambda) = a_5\lambda^5 + a_4\lambda^4 + a_3\lambda^3 + a_2\lambda^2 + a_1\lambda + a_0$. In this case, define $p(1) = 1 + a_4 + a_3 + a_2 + a_1 + a_0$ and $p(-1) = -1 + a_4 - a_3 + a_2 - a_1 + a_0$;

$$p(1) = (\beta\sigma)^{-1}((\delta_4 + \delta_5)(1 - \beta) + \kappa(\delta_3 - 1) + (\delta_1 + \delta_2)\kappa) \tag{A.8}$$

$$p(-1) = -(\beta\sigma)^{-1}((\delta_4 - \delta_5)(1 + \beta) + \kappa\delta_3 + (\delta_1 - \delta_2 + 1)(\kappa + 2\sigma + 2\beta\sigma)) \tag{A.9}$$

Conditions (C.13) and (C.14) in Woodford [2011] are necessary for both Cases II and III (and they also rule out Case I). These two conditions are that $p(1) > 0$ and $p(-1) < 0$. Notice that when $\eta_i \geq 0$, the following condition is sufficient for determinacy, since it applies condition A.9.

$$|(\beta\sigma)^{-1}((\delta_4 + \delta_5)(1 - \beta) + \kappa(\delta_3 - 1) + (\delta_1 + \delta_2)\kappa)| > 0 \tag{A.10}$$

■

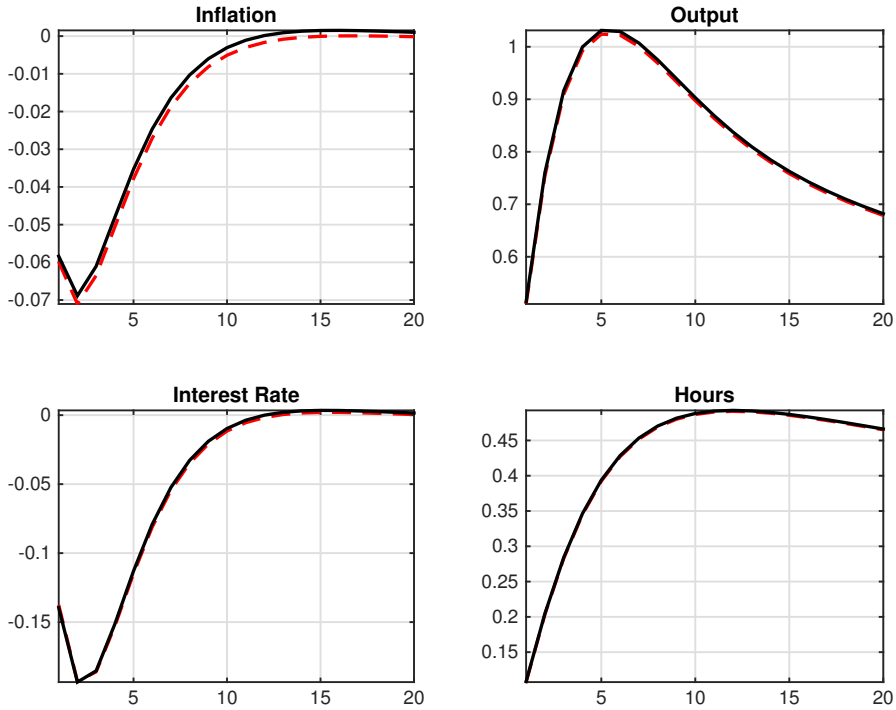
Appendix B

What are Monetary Policy Shocks?

B.1 Dynamic Responses

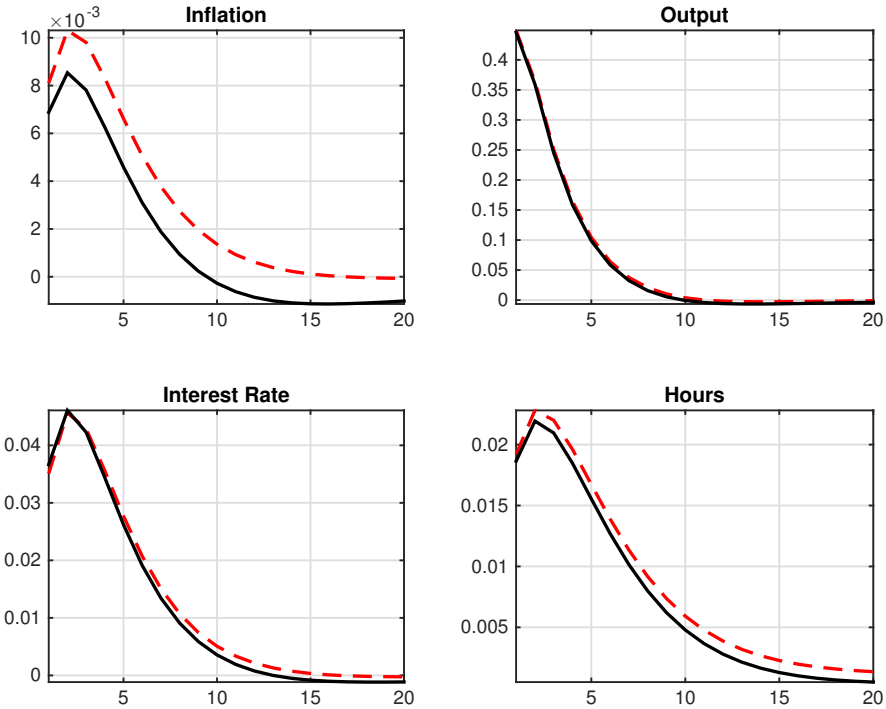
Figures B.1 through to B.7 summarize the impact of the structural shocks on inflation, output, interest rate and hours under a fixed target model, and a time-varying target model. Since the estimated structural shocks are remarkably similar under both models, these responses are very similar across both specifications of the inflation target. Since the AR(1) time-varying inflation target best fits the data, I only focus on this specification. I compare the impact of these shocks with a fixed inflation target model. Since the estimated models have the same structure, and the same estimates of the structural shocks, the impact on inflation, output, interest rate and labor hours are very similar.

Figure B.1: Effect of Productivity shock



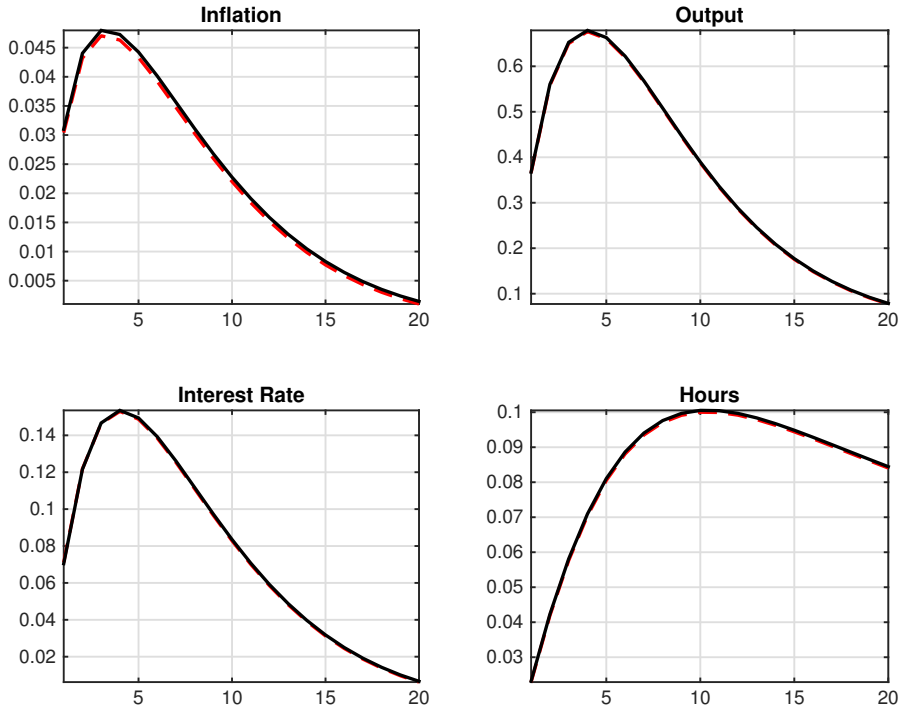
This figure plots the impulse response of inflation, output, hours and interest rate to a **productivity shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.2: Effect of Asset Premium Shock



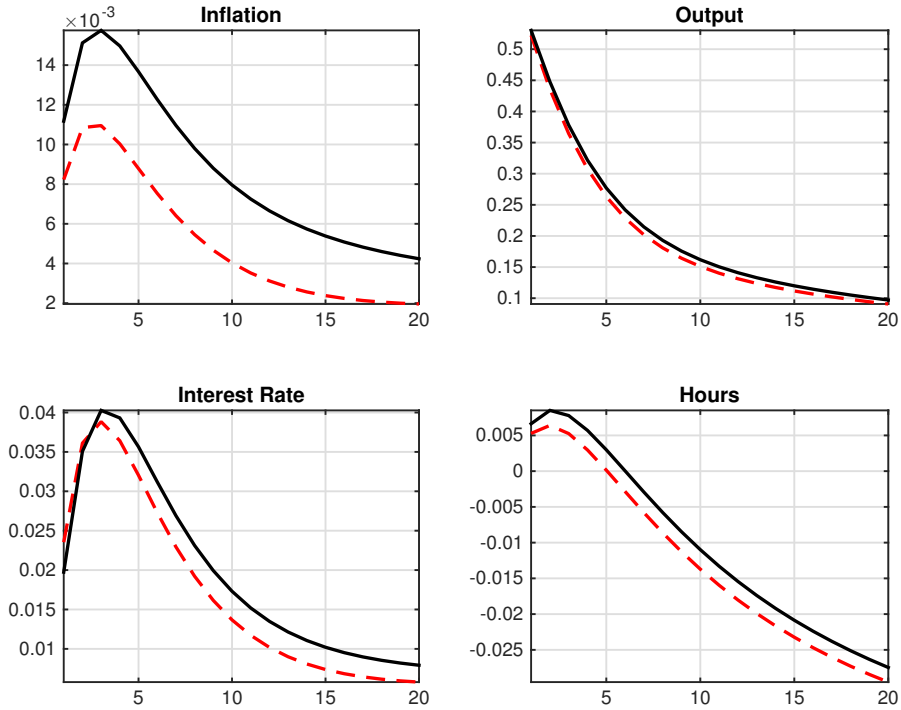
This figure plots the impulse response of inflation, output, hours and interest rate to an **asset premium shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.3: Effect of Investment-Specific Technology Shock



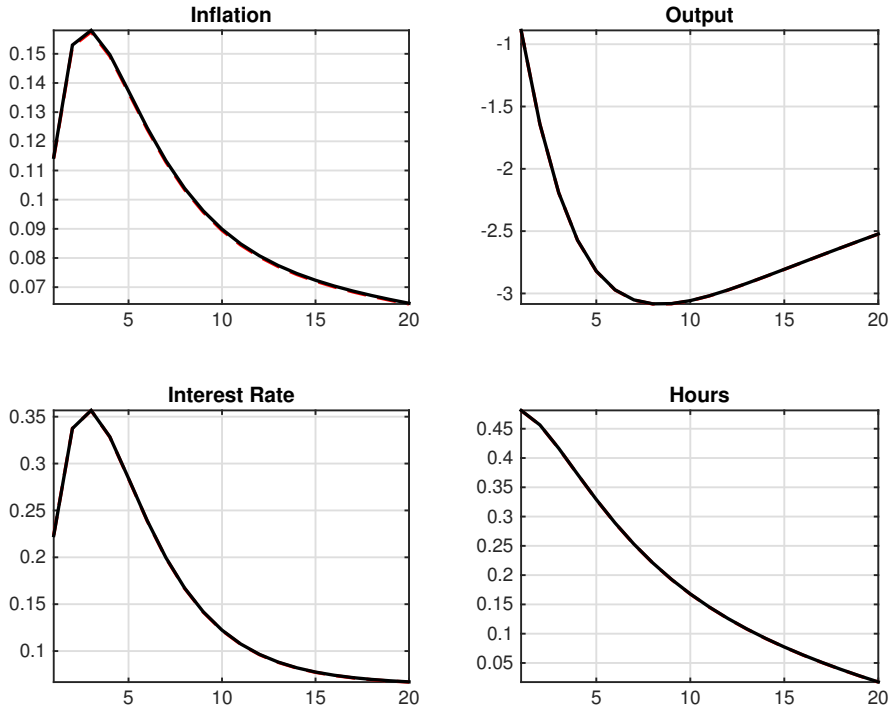
This figure plots the impulse response of inflation, output, hours and interest rate to an **investment-specific technology shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.4: Effect of Demand Shock



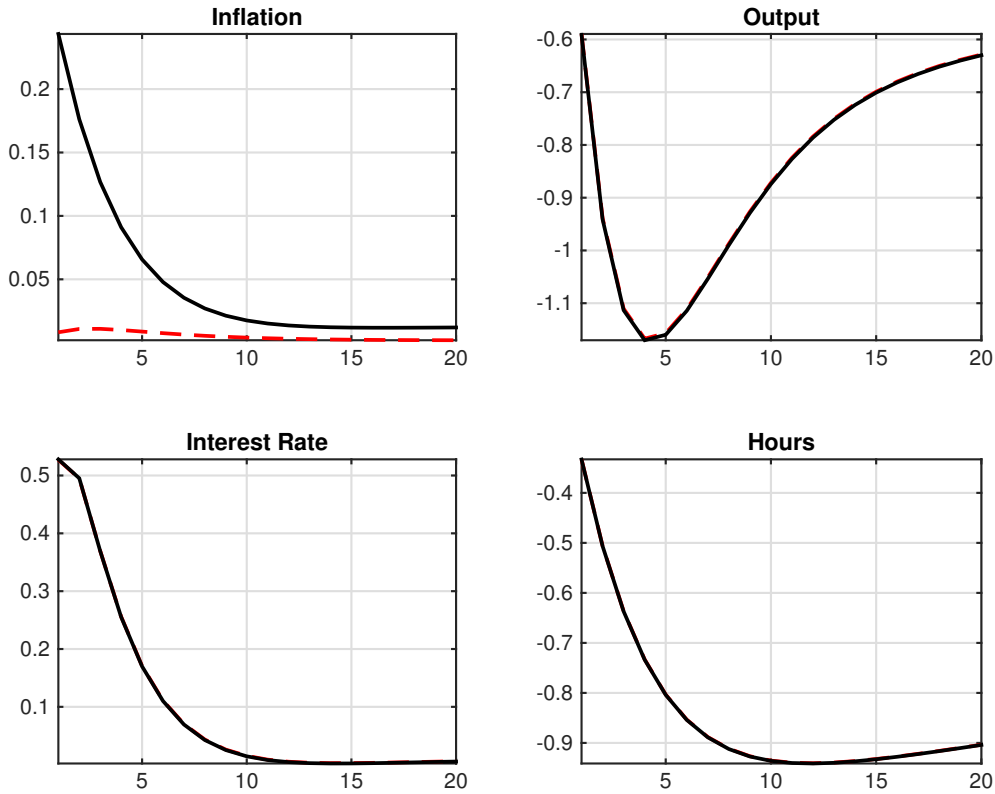
This figure plots the impulse response of inflation, output, hours and interest rate to a **demand shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.5: Effect of Wage Mark-up Shock



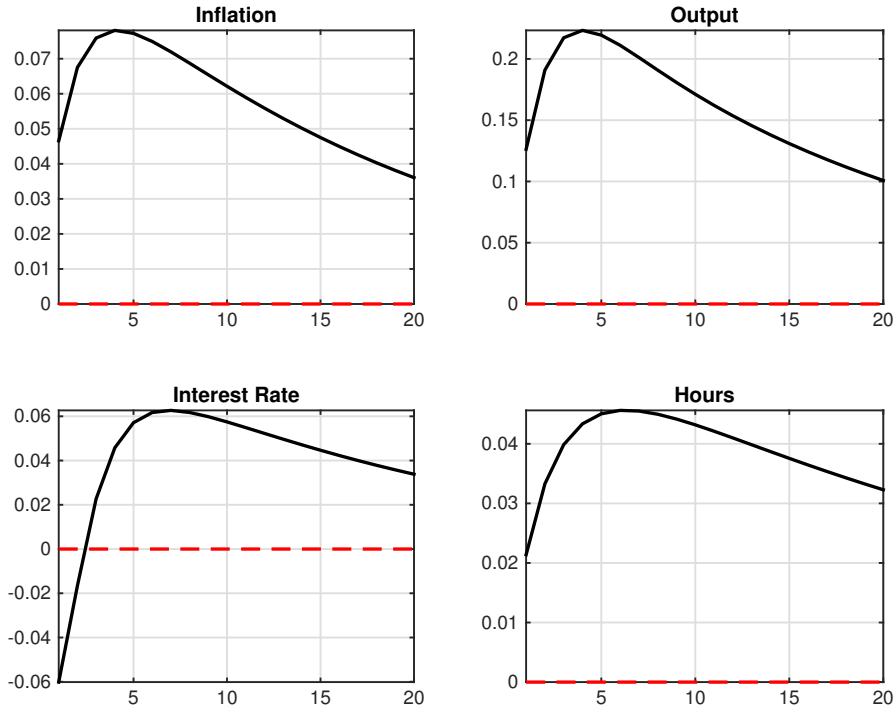
This figure plots the impulse response of inflation, output, hours and interest rate to a **wage mak-up shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.6: Effect of Supply Shock



This figure plots the impulse response of inflation, output, hours and interest rate to a **supply shock**. The red dotted lines represent IRF's under a fixed inflation target, and the solid black line represents IRF's based on a time-varying inflation target.

Figure B.7: Effect of Inflation Target Shock



The solid black line represents impulse response of inflation, output, hours and interest rate to a **shock to the inflation target.**

B.2 Robustness across Different Series of the Inflation Target

As discussed in the text, I test the fit of the model across multiple series of the extrapolated inflation target. This allows me to identify the best-fit inflation target series before using it to estimate the complete model.

Table B.1: Model-Fit (Comparison) 1959:1 - 2004:75

	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	Fixed	TV	Fixed	TV	Fixed	TV	Fixed	TV	Fixed	TV
ϕ_π	3	3	2	2	4	4	2.5	2.5	3	3
ϕ_y	0.05	0.05	0.1	0.1	0.05	0.05	0.1	0.1	0.05	0.05
ρ_r	0.25	0.25	0.05	0.05	0.25	0.25	0.1	0.1	0.75	0.75
ρ_v	0.32	0.24	0.29	0.18	0.90	0.21	0.38	0.27	0.41	0.38
σ_v	0.26	0.25	0.25	0.24	0.54	0.26	0.26	0.25	0.27	0.32
δ_a	-	0.0058	-	0.0137	-	0.0033	-	0.0028	-	-0.0005
δ_g	-	0.0055	-	0.0051	-	0.0090	-	-0.0036	-	-0.0013
δ_b	-	-0.0068	-	-0.0018	-	0.0026	-	-0.0109	-	0.0009
δ_i	-	-0.0030	-	0.0014	-	-0.0026	-	-0.0115	-	-0.0023
δ_w	-	-0.0015	-	-0.0157	-	0.0035	-	-0.0117	-	-0.0091
δ_p^p	-	-0.0083	-	-0.009	-	-0.0055	-	-0.0068	-	-0.0042
LL	-1111.8	-921.27	-1090.2	-922.07	-1148.7	-933.05	-1112.68	-929.63	-1114.4	-1035.6

The table presents the estimated values of the monetary policy parameters using different series for the inflation target, and compares it with a fixed inflation target. The first panel corresponds to the value of the policy parameters which is used to extrapolate the inflation target in section 3.2. The second panel corresponds to values of the process for monetary policy shocks under fixed and time varying inflation target models. The third panel shows the estimated values of the response of the monetary authority to structural shocks, while the last panel presents the marginal density of the model using Geweke [1999] modified harmonic mean estimator.

B.3 Robustness across Other Specifications

To deal with potential misspecification in the Fed's feedback rule such as other ways structural shocks may enter the feedback rule independently of the target, I estimate the complete model with different specifications of the feedback rule. For the three baseline cases as before, I estimate a model with a fixed inflation target a time-varying inflation target driven by structural shocks, and an AR(1) target model. The model is further estimated using six possible misspecifications in the feedback rule; first, when the inflation target is constant and there may be an omitted variable, θ_t, which is driven by the six structural shocks, and second when we have an AR(1) time-varying inflation target, with θ_t assumed to be driven by the six structural shocks. Third, the model is estimated using the unfiltered series, that is, the residual from the feedback rule. The motivation for including a noisy target is discussed in Tetlow [2008], who suggests that the implicit inflation target may have been subject to considerable randomness. Different combinations of structural shocks are allowed to enter in the time-varying inflation target, as potential misspecifications cases four and five. Finally an ARMA(1,1) process for the inflation target in the otherwise standard feedback rule is also estimated. Table B.13 summarizes the results from the different specifications of the inflation target.

Fixed target model Estimate the full model with a fixed inflation target.

Time-varying target model Estimate the full model with a time-varying inflation target, with the inflation target driven by the six structural shocks.

AR(1) target Estimate the case where the movement in the target was exogenous and not driven by the Central Bank responding to structural shocks.

$$\pi_t^T = \rho_\pi \pi_{t-1}^T + \epsilon_\pi \tag{B.1}$$

Comparison with misspecified Taylor Rule - (a) A potential misspecification in the Taylor rule is considered, where θ_t is driven by the six structural shocks, and is identified as the noisy component of the Taylor rule, using the Kalman filter and the inflation target is kept fixed to zero (the steady state inflation in this model).

$$i_t = \rho_r i_{t-1} + (1-\rho_r)(\phi_\pi \pi_t + \phi_y \tilde{y}_t) + \theta_t + v_t \tag{B.2}$$

Comparison with misspecified Taylor Rule - (b)

$$i_t = \rho_r i_{t-1} + (1-\rho_r)(\phi_\pi (\pi_t - \pi_t^T) + \phi_y \tilde{y}_t) + \theta_t + v_t \tag{B.3}$$

As before θ_t is driven by the 6 structural shocks in the model, and the data series is identified as the noisy component of the Taylor rule, using the Kalman filter, and the movement in the inflation target is now exogenous following an AR(1) process, as shown in equation B.1 and therefore not driven by the Central Bank responding to structural shocks through the inflation target.

Model with noisy target I use the unfiltered series for the inflation target, and allow it to be a function of the six structural shocks in the model.

Model with alternate specification of Target - (a) The target is set to evolve as a function of a subset of the shocks in the model, that is, productivity, government spending and investment and finance premium shocks.

Model with alternate specification of Target - (b) The target is set to evolve as a function of just the nominal structural shocks in the economy, that is, the cost-push and wage shocks.

Model with ARMA(1,1) Target The target is introduced as an ARMA(1,1) process.

$$\pi_t^T = \rho_\pi \pi_{t-1}^T + \eta_t^\pi + \rho_{\pi^a} \eta_{t-1}^\pi \tag{B.4}$$

While the results strongly favour a model with a time-varying inflation target as compared to a model with a fixed inflation target, the Bayesian Information Criterion (BIC) suggests that the model with an AR(1) inflation target is preferred over a model with an endogenous inflation target, that is, the one driven by the six structural shocks. This result back the claim made by Ireland [2005], who shows that there is little evidence to suggest that the movement in inflation target was driven by structural shocks. At the same time, the model favours a time-varying inflation target as compared to a fixed target model, which has important consequences for monetary policy shocks, as well as volatility in the economy, as discussed in the main text. A model with an AR(1) inflation target and an omitted variable θ_t driven by the six structural shocks does better than a fixed target model, which seems to suggest that somehow the structural shocks may enter the feedback rule, though independently of the inflation target and beyond those captured by changes in inflation and the output gap. The model with only an omitted variable and a noisy target rank last as suggested by the Bayesian Information Criterion (BIC).

B.4 Data and Estimation

B.4.1 Data

I use seven key macroeconomic quarterly US time series as observable variables: the log difference of real GDP, real consumption, real investment and the real wage, log hours worked, the log difference of the GDP deflator and the Federal Funds rate. All data are available from the FRED database. The data for the inflation target is extrapolated in the main text, and its log difference is used in the estimation in order to harmonise this series with the data on inflation.

B.4.2 Estimation

The following section describes the algorithm used to compute the Metropolis-Hastings procedure:

1. Choose a starting value or prior for our parameters Θ. For the fixed target model, Θ is composed of 36 parameters, and Θ for the time-varying inflation target models (AR(1) and structural) compose of 39 and 45 parameters respectively.

2. Draw Θ^* from $J_t(\Theta^*|\Theta^{t-1})$. The jumping distribution $J_t(\Theta^*|\Theta^{t-1})$ determines where we move to in the next iteration of the Markov chain and contains the support of the posterior.

3. Compute acceptance ratio r, according to:

$$r = \frac{p(\Theta^*|y)/J_t(\Theta^*|\Theta^{t-1})}{p(\Theta^{t-1}|y)/J_t(\Theta^{t-1}|\Theta^*)} \tag{B.5}$$

   If our candidate draw has higher probability than our current draw, then our candidate is better so we definitely accept it. Otherwise, our candidate is accepted according to the ratio of the probabilities of the candidate and current draws.

4. Accept Θ^* as Θ^t with probability $min(r, 1)$. If Θ^* is not accepted, then Θ^t $= \Theta^{t-1}$. Candidate draws with higher density than the current draw are always accepted.

A sample of 250000 draws was created, with 5 Metropolis-Hastings chains, and the first 20% of the sample was rejected. The model is estimated over the full sample period from 1959:I till 2004:IV[1] Following Smets and Wouters [2007] the

[1]In the last section of the chapter I further estimate the model over two sub periods (1959:I-1979:II and 1984:I- 2004:IV) in order to investigate the stability of the estimated parameters.

corresponding measurement equation is:

$$Y_t = \begin{pmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ dlHOURS_t \\ dlP_t \\ FEDFUNDS_t \\ dlPT_t \end{pmatrix} = \begin{pmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{l} \\ \bar{\pi} \\ \bar{r} \\ \bar{\pi}^T \end{pmatrix} + \begin{pmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ i_t - i_{t-1} \\ w_t - w_{t-1} \\ l_t \\ \pi_t \\ r_t \\ \pi_t^T \end{pmatrix} \tag{B.6}$$

where l and dl stand for 100 times log and log difference, respectively. Consumption, real GDP, investment and wages share a common trend growth rate, 100(γ - 1). $\bar{\pi} = 100(\Pi_* - 1)$ is the quarterly steady-state inflation rate; and $\bar{r} = 100(\beta^{-1}\gamma^{\sigma_c}\Pi_* - 1)$ is the steady-state nominal interest rate. Given the estimates of the trend growth rate and the steady-state inflation rate, the latter will be determined by the estimated discount rate. $\bar{l}$ is steady-state hours worked, which is normalized to equal zero. The quarterly steady state target inflation rate is calculated by $\bar{\pi}^T = 100(\Pi_*^T - 1)$. Next, I discuss the choice of the prior distribution used in my estimation.

B.4.3 Prior Selection

While most of the priors are selected with a similar approach as Smets and Wouters [2007], in this section I motivate the selection of the priors for the Taylor rule. Five parameters are fixed in the estimation procedure. The quarterly depreciation rate δ is fixed at 0.025, and the exogenous spending-GDP ratio g_y is set at 18%. Both of these parameters would be difficult to estimate unless the investment and exogenous spending ratios would be directly used in the measurement equation. Three other parameters are clearly not identified: the steady-state mark-up in the labor market (λ_w), which is set at 1.5, and the curvature parameters of the

Kimball aggregators in the goods and labor market (ϵ_p and ϵ_w), which are both set at 10. The parameters of the utility function are assumed to be distributed as follows. The intertemporal elasticity of substitution is set at 1.5 with a standard error of 0.375; the habit parameter is assumed to fluctuate around 0.7 with a standard error of 0.1 and the elasticity of labor supply is assumed to be around 2 with a standard error of 0.75. These are all quite standard calibrations. The prior on the adjustment cost parameter for investment is set around 4 with a standard error of 1.5 and the capacity utilisation elasticity is set at 0.5 with a standard error of 0.15. The share of fixed costs in the production function is assumed to have a prior mean of 0.25. Finally, there are the parameters describing the price and wage setting. The 'Calvo' probabilities are assumed to be around 0.5 for both prices and wages, suggesting an average length of price and wage contracts of half a year. The prior mean of the degree of indexation to past inflation is also set at 0.5 in both goods and labor markets, which is somewhat larger than the findings in the micro econometric studies based on U.S. data.

The priors on the stochastic processes are harmonised as much as possible. The standard errors of the innovations are assumed to follow an inverse-gamma distribution with a mean of 0.10 and two degrees of freedom, which corresponds to a rather loose prior. The persistence of the AR(1) processes is beta distributed with mean 0.5 and standard deviation 0.2. A similar distribution is assumed for the MA parameter in the process for the price and wage mark-up. The quarterly trend growth rate is assumed to be Normal distributed with mean 0.4 (quarterly growth rate) and standard deviation 0.1. The steady-state inflation rate and the discount rate are assumed to follow a gamma distribution with a mean of 2.5% and 1% on an annual basis. The parameters describing the monetary policy rule are based on a different specifications of the Taylor rule, each of which imply a unique mapping of the interest rate, inflation, output gap to the inflation target. The parameters δ_a, δ_b, δ_g, δ_i, δ_w and δ_p are set to 0, and allowing the model's estimation to suggest the complete estimation of these parameters. While previous studies

on the subject do not have a time series for the inflation target, I have estimated various possible estimates of the inflation target, and allow the complete model to imply the most likely estimates of these parameters. Finally, ρ_π are set to those estimated in the section 3.2.

Table B.13: Feedback Rule Robustness, 1959q1 - 2004q3

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
ρ_v	0.32	0.23	0.18	0.80	0.42	0.25	0.14	0.20	0.17
σ_v	0.26	0.25	0.25	0.45	0.47	0.26	0.25	0.26	0.25
δ_a	-	0.0053	-	0.0175	-0.0077	-0.013	-0.0031	-	-
δ_g	-	0.0090	-	-0.0138	0.0051	0.0283	0.0063	-	-
δ_b	-	-0.0073	-	-0.0033	-0.0058	-0.0071	0.0076	-	-
δ_i	-	0.0019	-	0.0032	0.0073	-0.0108	0.0042	-	-
δ_w	-	0.0019	-	0.0068	-0.0071	0.0019	-	-0.0190	-
δ_p^p	-	-0.0077	-	-0.0013	-0.0127	-0.0151	-	-0.0045	-
LL(MHME)	-1104.5	-917.9	-921.2	-1128.1	-999.51	-1186.6	-996.28	-940.23	-994.43

The table presents the estimated values of the monetary policy parameters using different specifications of the inflation target. The first panel represents the estimated monetary policy shocks under each specification, while panel 3 reports the marginal density of the model using Geweke [1999] modified harmonic mean estimator.

Bibliography

Aiyar, Shekhar, Charles W Calomiris, and Tomasz Wieladek, "Does Macro-Prudential Regulation Leak? Evidence from a UK Policy Experiment," *Journal of Money, Credit and Banking*, 2014, *46* (s1), 181–214.

Andrés, Javier, J David López-Salido, and Edward Nelson, "Money and the natural rate of interest: Structural estimates for the United States and the euro area," *Journal of Economic Dynamics and Control*, 2009, *33* (3), 758–776.

Bache, Ida Wolden and Kai Leitemo, "The price puzzle: Mixing the temporary and permanent monetary policy shocks," Technical Report, Norges Bank 2008.

Ball, Christopher P and Javier Reyes, "Announcement Effects in Small Open Economy Inflation Targeting Regimes," 2007.

Ball, Laurence, "Another Look at Long-Run Money Demand," NBER Working Papers 6597, National Bureau of Economic Research, Inc June 1998.

Bean, Charles Richard, "Asset prices, financial imbalances and monetary policy: are inflation targets enough?," 2003.

Beckworth, David and Joshua R Hendrickson, "Nominal GDP Targeting and the Taylor Rule on an Even Playing Field."

Belaygorod, Anatoliy and Michael J Dueker, "Discrete monetary policy changes and changing inflation targets in estimated dynamic stochastic gen-

eral equilibrium models," *REVIEW-FEDERAL RESERVE BANK OF SAINT LOUIS*, 2005, *87* (6), 719.

Belongia, Michael T and Dallas S Batten, "Selecting an intermediate target variable for monetary policy when the goal is price stability," *Federal Reserve Bank of St. Louis Working Paper Series*, 1992, (1992-008).

Benati, Luca and Haroon Mumtaz, "US evolving macroeconomic dynamics: a structural investigation," 2007.

Bernanke, Ben and Frederic Mishkin, "Central Bank Behavior and the Strategy of Monetary Policy: Observations From Six Industrialized Countries," Working Paper 4082, National Bureau of Economic Research May 1992.

_ **and Mark Gertler**, "Monetary policy and asset price volatility," Technical Report, National bureau of economic research 2000.

Bernanke, Ben S and A Blinder, "The Federal Funds Rate and the Trasmission of Monetary Policy," *American Economic Review*, 1992, *82*, 901–22.

_ **and Ilian Mihov**, "Measuring monetary policy," *The Quarterly Journal of Economics*, 1998.

Bianchi, Francesco, "Regime switches, agents' beliefs, and post-world war ii us macroeconomic dynamics," *The Review of Economic Studies*, 2012, p. rds032.

Blanchard, Olivier Jean and Charles M Kahn, "The Solution of Linear Difference Models under Rational Expectations," *Econometrica*, July 1980, *48* (5), 1305–11.

Boivin, Jean, "Has US Monetary Policy Changed? Evidence from Drifting Coefficients and Real-Time Data," NBER Working Papers 11314, National Bureau of Economic Research, Inc May 2005.

_ **and Marc Giannoni**, "Assessing changes in the monetary transmission mechanism: a VAR approach," *Federal Reserve Bank of New York Economic Policy Review*, 2002, *8* (1), 97–111.

Bryant, Ralph C, Peter Hooper, and Catherine L Mann, *Evaluating policy regimes: new research in empirical macroeconomics*, Brookings Inst Pr, 1993.

Burns, Arthur F, "Anguish of Central Banking, The," *Fed. Res. Bull.*, 1979, *73*, 687.

Calvo, Guillermo A, "Staggered prices in a utility-maximizing framework," *Journal of monetary Economics*, 1983, *12* (3), 383–398.

Canova, Fabio and Tobias Menz, "Does money matter in shaping domestic business cycles? An international investigation," *Journal of Money, Credit and Banking*, 2011, *43* (4), 577–607.

Carlstrom, Charles T and Timothy S Fuerst, "Money growth rules and price level determinacy," *Review of Economic Dynamics*, 2003, *6* (2), 263–275.

Carte, D, Giampaolo Galli, and Salvatore Rebechini, "Exchange Rates Can be Managed!," *International Economic Insights*, 1992, *3*, 17–21.

Castelnuovo, Efrem, "Estimating the Evolution of Money's Role in the U.S. Monetary Business Cycle," *Journal of Money, Credit and Banking*, 02 2012, *44* (1), 23–52.

_ , "Estimating the evolution of moneyâĂŹs role in the US monetary business cycle," *Journal of Money, Credit and Banking*, 2012, *44* (1), 23–52.

_ , "Fitting US trend inflation: a rolling-window approach," *Advances in Econometrics*, 2012, *28*, 201.

Cecchetti, Stephen G. and Robert W. Rich, "Structural estimates of the U.S. sacrifice ratio," Technical Report 1999.

Chan, Joshua C.C., "Moving average stochastic volatility models with application to inflation forecast," *Journal of Econometrics*, 2013, *176* (2), 162 – 172.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans, "Monetary policy shocks: What have we learned and to what end?," *Handbook of macroeconomics*, 1999, *1*, 65–148.

_ , _ , and _ , "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of political Economy*, 2005, *113* (1), 1–45.

Clarida, Richard, Jordi Gali, and Mark Gertler, "Monetary policy rules in practice Some international evidence," *European Economic Review*, June 1998, *42* (6), 1033–1067.

_ , Jordi Galí, and Mark Gertler, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *The Quarterly Journal of Economics*, 2000, *115* (1), 147–180.

Cochrane, John H, "Determinacy and identification with Taylor rules," Technical Report, National Bureau of Economic Research 2007.

Cogley, Timothy, "Adapting to instability in money demand: Forecasting money growth with a time-varying parameter model," *Economic Review-Federal Reserve Bank of San Francisco*, 1993, (3), 35.

_ and Thomas J. Sargent, "Drift and Volatilities: Monetary Policies and Outcomes in the Post WWII U.S," *Review of Economic Dynamics*, April 2005, *8* (2), 262–302.

_ , Giorgio E Primiceri, and Thomas J Sargent, "Inflation-gap persistence in the US," *NBER Working Paper*, 2008, (w13749).

Coibion, Olivier and Yuriy Gorodnichenko, "Monetary Policy, Trend Inflation, and the Great Moderation: An Alternative Interpretation," *American Economic Review*, February 2011, *101* (1), 341–70.

Cook, Timothy Q., "Determinants of the Federal funds rate: 1979 - 1982," Technical Report 1988.

Cooper, J Phillip and Stanley Fischer, "Simulations of Monetary Rules in the FRB-MIT-Penn Model," *Journal of Money, Credit and Banking*, 1972, *4* (2), 384–396.

Curdia, Vasco and Michael Woodford, "Credit spreads and monetary policy," *Journal of Money, Credit and Banking*, 2010, *42* (s1), 3–35.

Davig, Troy and Eric M Leeper, "Generalizing the Taylor principle," Technical Report, National Bureau of Economic Research 2005.

DeRosa, Paul and Gary H. Stern, "Monetary control and the federal funds rate," *Journal of Monetary Economics*, April 1977, *3* (2), 217–230.

Dominguez, Kathryn, "The informational role of official foreign exchange intervention operations: the signalling hypothesis," *Exchange rate efficiency and the behavior of international asset markets*, 1992, pp. 41–80.

Dueker, Michael J, "Narrow vs. broad measures of money as intermediate targets: some forecast results," *Federal Reserve Bank of St. Louis Review*, 1995, *77* (January/February 1995).

E, Jr Lucas Robert, "Two Illustrations of the Quantity Theory of Money," *American Economic Review*, December 1980, *70* (5), 1005–14.

Eichenbaum, Martin, "'Interpreting the macroeconomic time series facts: The effects of monetary policy' : by Christopher Sims," *European Economic Review*, June 1992, *36* (5), 1001–1011.

Estrella, Arturo and Frederic S Mishkin, "Is there a role for monetary aggregates in the conduct of monetary policy?," *Journal of monetary economics*, 1997, *40* (2), 279–304.

Evans, George W and Seppo Honkapohja, "Adaptive learning and monetary policy design," *Journal of Money, Credit, and Banking*, 2003, *35* (6), 1045–1072.

_ **and** _ , "Friedman's money supply rule vs. optimal interest rate policy," *Scottish Journal of Political Economy*, 2003, *50* (5), 550–566.

Favara, Giovanni and Paolo Giordani, "Reconsidering the role of money for output, prices and interest rates," *Journal of Monetary Economics*, 2009, *56* (3), 419–430.

Fed, US, "The Federal Reserve System: Purposes and Functions, 9th edn (Washington, DC: US Fed)," 2005.

Feldstein, Martin, "The Case Against Trying To Stabilize The Dollar," *The American Economic Review*, 1989, *79* (2), 36.

Fischer, Stanley, "Rules versus discretion in monetary policy," Technical Report, National Bureau of Economic Research 1988.

Friedman, Benjamin M, "Targets, instruments, and indicators of monetary policy," *Journal of Monetary Economics*, 1976, *1* (4), 443–473.

_ , "The value of intermediate targets in implementing monetary policy," Technical Report, National Bureau of Economic Research 1984.

Friedman, Benjamin M., "The Rise and Fall of Money Growth Targets as Guidelines for U.S. Monetary Policy," Working Paper 5465, National Bureau of Economic Research February 1996.

Friedman, Benjamin M, "The role of interest rates in Federal Reserve policy-making," Technical Report, National Bureau of Economic Research 2000.

_ **and Kenneth N Kuttner**, "Implementation of monetary policy: How do central banks set interest rates?," Technical Report, National Bureau of Economic Research 2010.

_ , _ , **Mark Gertler, and James Tobin**, "A price target for US monetary policy? Lessons from the experience with money growth targets," *Brookings papers on economic activity*, 1996, pp. 77–146.

Friedman, Milton, "A monetary and fiscal framework for economic stability," *The American Economic Review*, 1948, pp. 245–264.

_ **and Anna Jacobson Schwartz**, *A monetary history of the United States, 1867-1960*, Princeton University Press, 2008.

Fuhrer, Jeffrey C, "Optimal Monetary Palicy and Sacrifice Ratio," *Facing Monetary Policymakers*, 1994, p. 43.

Furlong, Frederick T, "International dimensions of US economic policy in the 1980s," *Economic Review-Federal Reserve Bank of San Francisco*, 1989, (2), 3.

Gali, Jordi, "New Perspectives on Monetary Policy, Inflation and the Business Cycle," CEPR Discussion Papers 3210, C.E.P.R. Discussion Papers February 2002.

_ , *Monetary Policy, inflation, and the Business Cycle: An introduction to the new Keynesian Framework*, Princeton University Press, 2009.

Gambacorta, Leonardo and Federico M Signoretti, "Should monetary policy lean against the wind?: An analysis based on a DSGE model with banking," *Journal of Economic Dynamics and Control*, 2014, *43*, 146–174.

Gambs, Carl M et al., "Federal reserve intermediate targets: Money or the monetary base?," *System*, 1979, *65*, 13–42.

Garcia, Gillian, "The right rabbit: Which intermediate target should the Fed pursue?," *Economic Perspectives*, 1984, (May), 15–31.

Garín, Julio, Robert Lester, and Eric Sims, "On the desirability of nominal GDP targeting," *Journal of Economic Dynamics and Control*, 2016, *69*, 21–44.

Gavin, William T, Benjamin D Keen, and Finn E Kydland, "Monetary policy, the tax code, and the real effects of energy shocks," *Review of Economic Dynamics*, 2014.

Gavin, WT, BD Keen, and MR Pakko, "The Monetary Instrument Matters, Federal Reserve Bank of St," Technical Report, Louis, Working Paper 2004-026a 2004.

Gelain, Paolo and Pelin Ilbas, "Monetary and macroprudential policies in an estimated model with financial intermediation," *National Bank of Belgium Working Paper*, 2014, (258).

Gertler, Mark and Peter Karadi, "A model of unconventional monetary policy," *Journal of monetary Economics*, 2011, *58* (1), 17–34.

Geweke, John, "Computational Experiments and Reality," Computing in Economics and Finance 1999 401, Society for Computational Economics March 1999.

Giannoni, Marc, *Model Uncertainty and Optimal Monetary Policy*, Princeton University, 2001.

Giannoni, Marc P, "Robust optimal monetary policy in a forward-looking model with parameter and shock uncertainty," *Journal of Applied Econometrics*, 2007, *22* (1), 179–213.

Girton, Lance, Dale W Henderson et al., *Central bank operations in foreign and domestic assets under fixed and flexible exchange rates*, Board of Governors of the Federal Reserve System, 1976.

Goodfriend, Marvin, "The monetary policy debate since October 1979: lessons for theory and practice," *Review*, 2005, (Mar), 243–262.

Goodhart, Charles AE, "What should central banks do? What should be their macroeconomic objectives and operations?," *The Economic Journal*, 1994, pp. 1424–1436.

Gordon, David B and Eric M Leeper, "The dynamic impacts of monetary policy: an exercise in tentative identification," *Journal of Political Economy*, 1994, pp. 1228–1247.

Hanson, Michael S., "Varying Monetary Policy Regimes: A Vector Autoregressive Investigation," Wesleyan Economics Working Papers 2006-003, Wesleyan University, Department of Economics January 2006.

Hanson, Samuel Gregory, Anil K Kashyap, and Jeremy C Stein, "A macroprudential approach to financial regulation," *Chicago Booth Research Paper*, 2010, (10-29).

Hodrick, Robert J and Edward C Prescott, "Postwar U.S. Business Cycles: An Empirical Investigation," *Journal of Money, Credit and Banking*, February 1997, *29* (1), 1–16.

Ireland, Peter N., "Changes in the Federal Reserve's Inflation Target: Causes and Consequences," Boston College Working Papers in Economics 607, Boston College Department of Economics January 2005.

_ , "On the Welfare Cost of Inflation and the Recent Behavior of Money Demand," *American Economic Review*, 2009, *99* (3), 1040–52.

Judd, John P. and Glenn D. Rudebusch, "Taylor's rule and the Fed, 1970-1997," *Economic Review*, 1998, pp. 3–16.

Justiniano, Alejandro and Giorgio E. Primiceri, "The Time-Varying Volatility of Macroeconomic Fluctuations," *American Economic Review*, June 2008, *98* (3), 604–41.

Kahn, James A., Margaret M. McConnell, and Gabriel Perez-Quiros, "On the causes of the increased stability of the U.S. economy," *Economic Policy Review*, 2002, (May), 183–202.

Kane, Edward J, "All for the best: The Federal Reserve Board's 60th annual report," *The American Economic Review*, 1974, pp. 835–850.

Karamouzis, Nicholas and Raymond Lombra, "Federal Reserve policymaking: An overview and analysis of the policy process," in "Carnegie-Rochester Conference Series on Public Policy," Vol. 30 Elsevier 1989, pp. 7–62.

Keating, John W, Andrew Lee Smith, and KS Lawrence, "Determinacy and indeterminacy in monetary policy rules with money," Technical Report, Mimeo., University of Kansas Department of Economics 2014.

Khan, Mr Mohsin S, *Current issues in the design and conduct of monetary policy* number 3-56, International Monetary Fund, 2003.

Kilponen, Juha and Kai Leitemo, "Model Uncertainty and Delegation: A Case for Friedman's k-Percent Money Growth Rule?," *Journal of Money, Credit and Banking*, 2008, *40* (2-3), 547–556.

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

_ , Kundan Kishor, and Charles R Nelson, "A time-varying parameter model for a forward-looking monetary policy rule based on real-time data," 2006.

Kozicki, Sharon and P.A. Tinsley, "Perhaps the FOMC did what it said it did : an alternative interpretation of the Great Inflation," Technical Report 2005.

Kydland, Finn E and Edward C Prescott, "Rules rather than discretion: The inconsistency of optimal plans," *The Journal of Political Economy*, 1977, pp. 473–491.

Larkin, John, Fred Levin, Paul Meek, Robert Roosa, and Irwin Sandberg, "A Review of Federal Reserve Policy Targets and Operating Guides in Recent Decades," 1988.

Leduc, Sylvain and Keith Sill, "Monetary policy, oil shocks, and TFP: accounting for the decline in US volatility," *Review of Economic Dynamics*, 2007, *10* (4), 595–614.

Leeper, Eric M, "Equilibria under 'active' and 'passive' monetary and fiscal policies," *Journal of monetary Economics*, 1991, *27* (1), 129–147.

Leeper, Eric M. and Tao Zha, "Modest policy interventions," *Journal of Monetary Economics*, November 2003, *50* (8), 1673–1700.

Leigh, Daniel, "Estimating the Federal Reserve's implicit inflation target: A state space approach," *Journal of Economic Dynamics and Control*, June 2008, *32* (6), 2013–2030.

Levin, Andrew T., Fabio M. Natalucci, and Jeremy M. Piger, "The macroeconomic effects of inflation targeting," *Review*, 2004, (Jul), 51–80.

Lubik, Thomas A. and Frank Schorfheide, "Testing for Indeterminacy: An Application to U.S. Monetary Policy," *American Economic Review*, 2004, *94* (1), 190–217.

Lubik, Thomas and Christian Matthes, "Indeterminacy and Learning: An Analysis of Monetary Policy in the Great Inflation," 2014.

Mccallum, Bennet T, "Robustness properties of a rule for monetary policy," in "Carnegie-Rochester conference series on public policy," Vol. 29 Elsevier 1988, pp. 173–203.

McCallum, Bennett T., "Price level determinacy with an interest rate policy rule and rational expectations," *Journal of Monetary Economics*, 1981, *8* (3), 319–329.

McCallum, Bennett T, "Specification and analysis of a monetary policy rule for Japan," Technical Report, National Bureau of Economic Research 1993.

_ , "Issues in the design of monetary policy rules," *Handbook of macroeconomics*, 1999, *1*, 1483–1530.

Mehra, Yash P, "An error-correction model of US M2 demand," *FRB Richmond Economic Review*, 1991, *77* (3), 3–12.

Meulendyke, Ann-Marie, "A review of Federal Reserve policy targets and operating guides in recent decades," *Quarterly Review*, 1988, (Aut), 6–17.

_ , "US monetary policy and financial markets," *Monograph*, 1998.

Milani, Fabio, "The Evolution of the Fed's Inflation Target in an Estimated Model under RE and Learning," Working Papers 060704, University of California-Irvine, Department of Economics September 2006.

Mishkin, Frederic S, "Housing and the monetary transmission mechanism," Technical Report, National Bureau of Economic Research 2007.

_ , *Monetary policy strategy*, Mit press, 2007.

of New York, Federal Reserve Bank, *Intermediate Targets and Indicators for Monetary Policy : A Critical Survey*, Federal Reserve Bank of New York, 1990.

Orphanides, Athanasios, "Monetary-Policy Rules and the Great Inflation," *American Economic Review*, May 2002, *92* (2), 115–120.

_ , "The quest for prosperity without inflation," *Journal of monetary Economics*, 2003, *50* (3), 633–663.

_ , "Monetary policy rules, macroeconomic stability, and inflation: A view from the trenches," *Journal of Money, Credit and Banking*, 2004, pp. 151–175.

_ , "Taylor rules," *Available at SSRN 999563*, 2007.

_ **and David W Wilcox**, *The opportunistic approach to disinflation*, Federal Reserve Board, 1996.

_ **and John C Williams**, "Monetary policy with imperfect knowledge," *Journal of the European Economic Association*, 2006, *4* (2-3), 366–375.

Perez-Quiros, Gabriel and Margaret M. McConnell, "Output Fluctuations in the United States: What Has Changed since the Early 1980's?," *American Economic Review*, December 2000, *90* (5), 1464–1476.

Pierce, James L, "Some rules for the conduct of monetary policy," *Controlling Monetary Aggregates. Boston: Federal Reserve Bank of Boston*, 1969, *13346.*

Poole, William, "Optimal choice of monetary policy instruments in a simple stochastic macro model," *The Quarterly Journal of Economics*, 1970, pp. 197–216.

Pozsar, Zoltan, Tobias Adrian, Adam B Ashcraft, and Haley Boesky, "Shadow banking," *Available at SSRN 1640545*, 2010.

Primiceri, Giorgio E., "Time Varying Structural Vector Autoregressions and Monetary Policy," *Review of Economic Studies*, 2005, *72* (3), 821–852.

Roberts, John M, "Monetary Policy and Inflation Dynamics. International Journal of Central Banking," *International Journal of Central Banking*, 2006, *2* (4), 193–230.

Romer, Christina D. and David H. Romer, "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz," Working Paper 2966, National Bureau of Economic Research May 1989.

Rotemberg, Julio J and Michael Woodford, "Interest rate rules in an estimated sticky price model," in "Monetary policy rules," University of Chicago Press, 1999, pp. 57–126.

Sargent, Thomas and Neil Wallace, ""Rational" Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule," *Journal of Political Economy*, 1975, *83* (2), 241–54.

Sargent, Thomas J, *The conquest of American inflation*, Princeton University Press, 2001.

_ **and Paolo Surico**, "Two illustrations of the quantity theory of money: Breakdowns and revivals," *The American Economic Review*, 2011, *101* (1), 109–128.

Sims, Christopher A, "A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy," *Economic theory*, 1994, *4* (3), 381–399.

_ , "Drift and breaks in monetary policy," *Manuscript, Princeton University*, 1999.

_ , "Stability and instability in US monetary policy behavior," *Unpublished Paper*, 2001.

Sims, Christopher A and Tao Zha, "Were there regime switches in US monetary policy?," *The American Economic Review*, 2006, pp. 54–81.

Sims, Eric, "Identification and Estimation of Interest Rate Rules in New Keynesian Models," 2008.

Smets, Frank and Rafael Wouters, "Shocks and frictions in US business cycles: A Bayesian DSGE approach," *The American Economic Review*, 2007, *97* (3), 586–606.

Söderström, Ulf, "Targeting inflation with a prominent role for money," Technical Report, Sveriges Riksbank Working Paper Series 2001.

Stein, Jeremy C, "Overheating in credit markets: origins, measurement, and policy responses," *speech, February*, 2013, *7*.

Stock, James H. and Mark W. Watson, "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, 1993, *61* (4), pp. 783–820.

_ **and** _ , "Has the Business Cycle Changed and Why?," NBER Working Papers 9127, National Bureau of Economic Research, Inc August 2002.

Summers, Peter M., "What caused the Great Moderation? : some cross-country evidence," *Economic Review*, 2005, (Q III), 5–32.

Sumner, Scott B, "Nominal GDP Targeting: A Simple Rule to Improve Fed Performance," *Cato J.*, 2014, *34*, 315.

Svensson, Lars EO, "How should monetary policy be conducted in an era of price stability?," Technical Report, National bureau of economic research 2000.

_ , "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules," *Journal of Economic Literature*, 2003, *41* (2), 426–477.

Svensson, Lars E.O., "Inflation Targeting," Working Paper 16654, National Bureau of Economic Research December 2010.

Svensson, Lars EO and Michael Woodford, "Implementing optimal policy through inflation-forecast targeting," in "The inflation-targeting debate," University of Chicago Press, 2004, pp. 19–92.

Taylor, John B, "Estimation and control of a macroeconomic model with rational expectations," *Econometrica: Journal of the Econometric Society*, 1979, pp. 1267–1286.

_ , "What would nominal GNP targetting do to the business cycle?," in "Carnegie-Rochester conference series on public policy," Vol. 22 North-Holland 1985, pp. 61–84.

_ , "Discretion versus policy rules in practice," in "Carnegie-Rochester conference series on public policy," Vol. 39 Elsevier 1993, pp. 195–214.

_ , "A historical analysis of monetary policy rules," in "Monetary policy rules," University of Chicago Press, 1999, pp. 319–348.

_ , "The Effectiveness of Central Bank Independence Versus Policy Rules," Technical Report 2013.

_ **and John C Williams**, "Simple and Robust Rules for Monetary Policy," *Handbook of Monetary Economics*, 2010, *3*, 829–859.

_ **and Michael Woodford**, *Handbook of macroeconomics*, Elsevier, 1999.

Teles, Pedro and Harald Uhlig, "Is quantity theory still alive?," Technical Report, National Bureau of Economic Research 2010.

_ **,** _ **, and João Valle e Azevedo**, "Is quantity theory still alive?," *The Economic Journal*, 2016.

Tetlow, Robert J, "Inflation targeting and target instability," *International Journal of Central Banking*, 2008, *4* (4), 151–192.

Walsh, Carl E, *Monetary theory and policy*, the MIT Press, 2003.

_ , "Speed Limit Policies: The Output Gap and Optimal Monetary Policy," *American Economic Review*, 2003, pp. 265–278.

Wascher, William et al., "Sacrifice ratios and the conduct of monetary policy in conditions of low inflation," 1999.

Williamson, John, "Exchange Rate Management," *The Economic Journal*, 1993, *103* (416), 188–197.

Woodford, Michael, "Optimal monetary policy inertia," Technical Report, National Bureau of Economic Research 1999.

_ , "The Taylor rule and optimal monetary policy," *American Economic Review*, 2001, pp. 232–237.

_ , *Interest and prices: Foundations of a theory of monetary policy*, princeton university press, 2011.