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Monetarism, Indeterminacy and the Great Inflation

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Monetarism, Indeterminacy and the Great Inflation*

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Abstract

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 FOMC meeting-level data propose a new channel of the policy mistakes that may have triggered indeterminacy during the Great Inflation. I show that 'passively' pursuing money growth objectives generates significantly larger welfare loss compared to alternative specifications of the monetary policy rule but 'active' money growth targeting drastically minimizes welfare loss. I confirm the relationship between money growth objectives and macroeconomic volatility using cross-country evidence.

Keywords: Money Growth Objectives, Time-Varying Policy, Indeterminacy, Macroeconomic Volatility

JEL classification: E41, E42, E51, E52, E58, E61, E65, O50

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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. (1998a) 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 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 ag-

[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)).

gregates'. 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 (2007). 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 presented in Clarida et al. (1998a) 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

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

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 results with this evidence 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 this type of monetary regime 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 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 is 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 and Smith (2013) by highlighting the critical relationship between nominal money and inflation in ensuring price level determinacy when the monetary authority pursues money growth objectives. My results contribute to the theoretical literature which has so far only focused on the response towards inflation as a pre-requisite of active policy (see for example Friedman (2000), Woodford (2001) and Carlstrom and Fuerst (2003)).

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

[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.

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 Burns paid more attention to money growth in the early 1970s (Burns (1987), 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. (1998a), and Coibion and Gorodnichenko (2011) than the conclusions 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. My results suggests that analyzing monetary policy in pre and post Volcker characterization may be misleading, as multiple policy regimes are estimated to have occurred during the 1970s, supporting the results presented in Sims and Zha (2006), Bianchi (2012) and Lubik et al. (2014).

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, supporting the claims made by Roberts (2006), Leduc and Sill (2007) and Taylor (2013). 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. My findings suggest that countries that pursue money growth objectives similar to the U.S may attain significant welfare gains by switching to a Taylor type specification.

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 3 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 4, I present international evidence of monetary aggregate targeting. Section 5 concludes, with suggestions for future research.

2. Model, Parameterization and Determinacy

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

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:

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

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \tag{2}$$

where π_t is inflation and x_t is the output gap.[5] Equation 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 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 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):

$$m_t^n = \eta_\pi p_t + \eta_x y_t - \eta_i i_t + \tau_t \tag{3}$$

Similar to Mehra (1991) and Söderström (2001), I take first differences to

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

obtain an expression for the growth rate of the nominal money stock:

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

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.[6] 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 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)).[7] Consequently, a meeting-specific feedback rule which captures the forward-looking behaviour

[6] 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 3.

[7] 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).

of the Fed can be written as follows:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi,t} E_t \pi_{t+j} + \psi_{x,t} E_t x_{t+j} + \psi_{m,t} E_t \Delta m^n_{t+j}] + c_t + \epsilon_t \tag{5}$$

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:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi} E_t \pi_{t+j} + \psi_{x} E_t x_{t+j} + \psi_{gy} E_t gy_{t+j}] + c_t + \epsilon_t \tag{6}$$

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, characterised by persistence ρ, and shock variance, σ.

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.[8] First, I derive a baseline price level determinacy condition for the general policy rule, and then focus on the different combinations of simple rules.

[8]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.

2.2.1. 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:*

$$(\beta\sigma)^{-1}(\delta_4(1-\beta) + \kappa(\delta_3 - 1) + \delta_5(1-\beta) + (\delta_1+\delta_2)\kappa) > 0 \tag{7}$$

$$-(\beta\sigma)^{-1}((\delta_4-\delta_5)(1+\beta) + \kappa\delta_3 + (\delta_1-\delta_2+1)(\kappa+2\sigma+2\beta\sigma)) < 0 \tag{8}$$

where δ_i *for* $i \in \{1,2,3,4,5\}$ *are convolutions of the policy parameters and 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 A.3.2

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

2.2.2. Responding to Output Gap and Inflation

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

$$i_t = \psi_\pi \pi_t + \psi_x x_t \tag{9}$$

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 7.[9]

$$(1-\beta)\psi_x + \kappa(\psi_\pi - 1) > 0 \tag{10}$$

As discussed in Galí (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.

2.2.3. Responding to Money Growth and Inflation

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

$$i_t = \psi_\pi \pi_t + \psi_{\Delta m} \Delta m_t^N \tag{11}$$

Setting ρ_1, ρ_2, and ψ_x equal to zero in condition 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:*

$$\eta_\pi \psi_{\Delta m} + \psi_\pi > 1 \tag{12}$$

Thus, the likelihood of determinacy is affected by the response to money

[9] We can ignore the second determinacy condition for this case, since expression 8 will boil down to a condition where the sum of two positive policy parameters and three structural parameters (which are positive by assumption).

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 12 collapses to the Taylor principle:

$$\psi_{\pi} > 1 \tag{13}$$

Therefore, under condition 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 12. To consider the implications for the nominal rate under the policy rule specified in equation 11, assume a permanent increase in inflation of size $d\pi$:

$$di = \psi_{\pi} d\pi + \psi_{\Delta m} d\Delta m \tag{14}$$

Simplifying the money demand relationship described in equation 3, the change in the nominal interest rates can be captured by:

$$di = (\psi_{\pi} + \eta_{\pi}\psi_{\Delta m}) d\pi \tag{15}$$

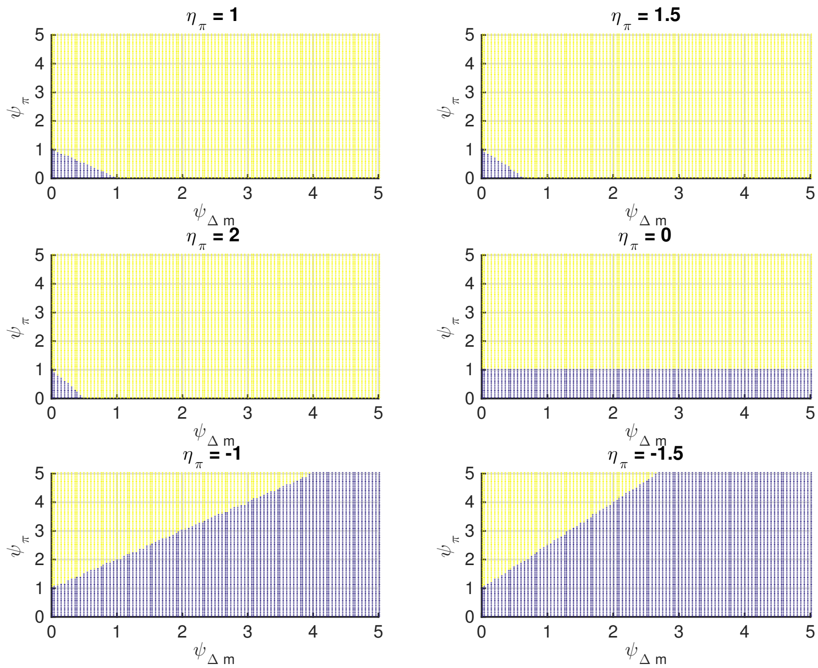
Condition 12 is equivalent to the term in brackets in equation 15 being greater than one, implying that the price level equilibrium will be unique under interest rate rule 11 whenever ψ_{π} and $\psi_{\Delta m}$ are sufficiently large (or are of the same sign) to guarantee that the real interest rate 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 18. This condition is similar to the determinacy condition outlined in Keating and Smith (2013), but is generalized to allow for variation in η_π.

The determinacy regions under multiple parameterizations of η_π are shown in Figure 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,[10] 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 and Smith (2013), 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.[11]

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

[11] 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 $\eta_x = 0$).

Figure 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.

2.2.4. Interest Rate Smoothing

Last, I analyze the case where the monetary authority responds to money growth and partially smoothes interest rates. Clarida et al. (1998b) 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:

$$i_t = \rho_1 i_{t-1} + \psi_{\Delta m}\Delta m_t \tag{16}$$

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 $i_t = \rho_1 i_t + \psi_{\Delta m}\Delta m_t$, the following condition is sufficient for determinacy:*[12]

$$\psi_{\Delta m} + \rho_1 > 1 \tag{17}$$

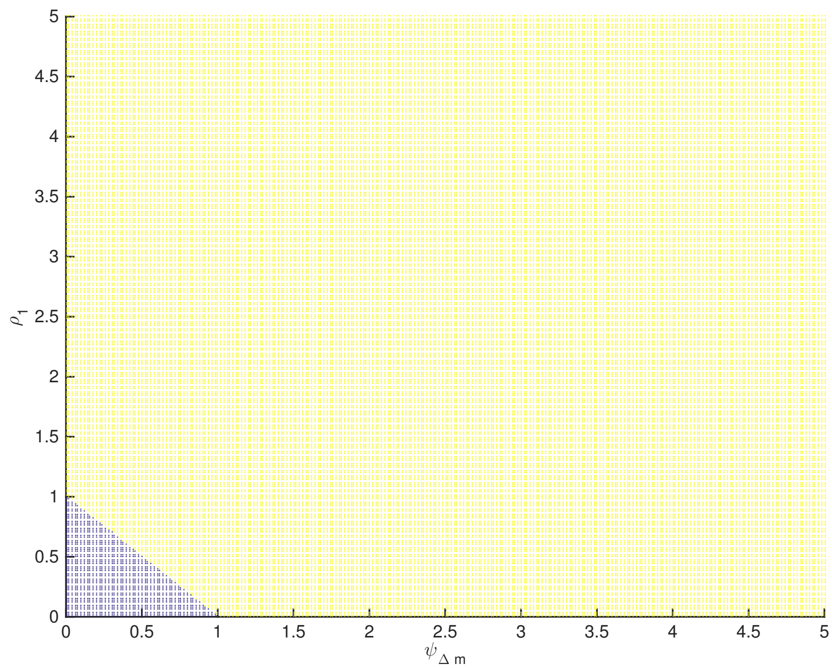
This result can be obtained by setting ρ_2, ψ_x and ψ_π equal to zero in equation 7. As before, consider the implications for the nominal rate under the monetary policy rule defined in equation 17 if there was a permanent increase in inflation of size $d\pi$.

$$di = \frac{\psi_{\Delta m}}{1-\rho_1} d\Delta m \tag{18}$$

If condition 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 2 plots the determinacy region for this result.

[12]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 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.

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 Galí (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 Galí (2009). Table 1 summarizes the baseline parameterization, split into structural and shock parameters, which are used to simulate the model.

Table 1: Baseline parameterization

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

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

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.

3.1. Empirical evidence

3.1.1. 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.

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[\psi_{\pi,t}\pi_t + \psi_{x,t}x_t + \psi_{m,t}\Delta m_t] + c_t + \epsilon_t \quad (19)$$

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 collected from the policy directives issued at the end of the FOMC meeting, and is collected from the Minutes.[13] 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

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

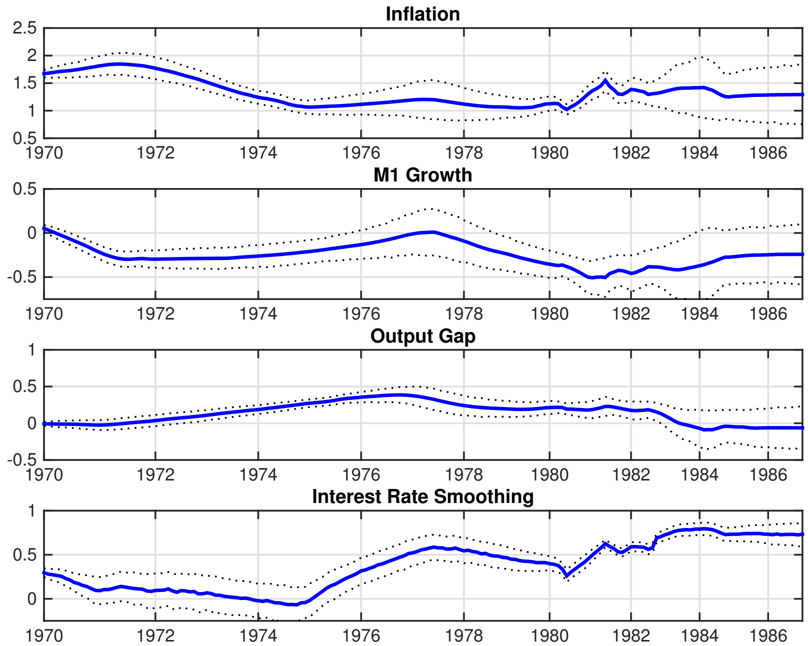
of the policy parameters is time-varying and follows a driftless random walk:[14]

$$\Omega_t = \Omega_{t-1} + \omega_t \tag{20}$$

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 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 3 and 4 present the results.

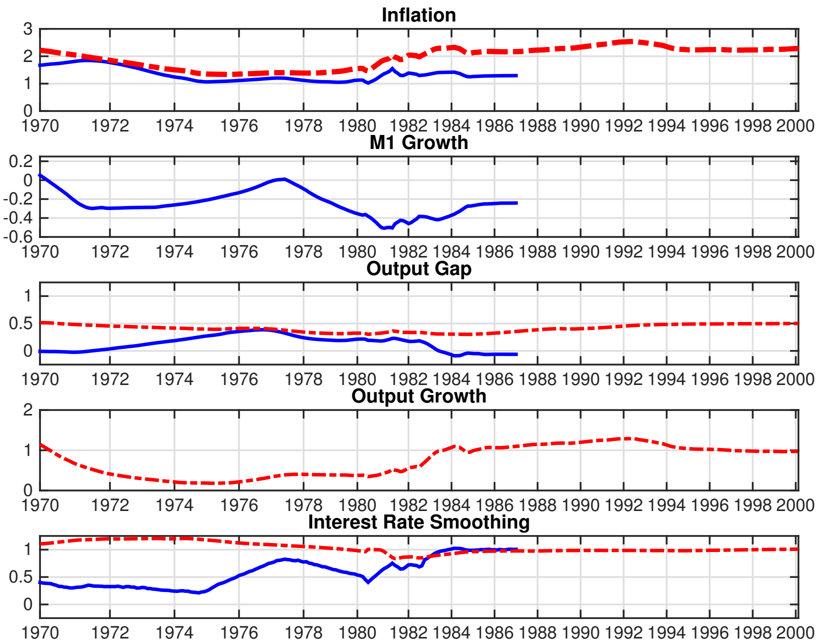
[14]To deal with any possible endogeneity issues, IV estimates are included in the appendix. Moreover, numerous tests were performed on meeting-level data to gauge the likelihood of collinearity. Similar to earlier literature, I find no concerns that may influence my baseline estimates. Second, I also compile a data set for M2 based on Greenbook/Policy directives, and repeat this estimation. M2 enters with a positive sign from 1975. However, combining the determinacy periods suggested by the policy rule with M2 does not change the results of this paper. These results are available upon request.

Figure 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 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 formalizing 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 for the entire sample. 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 (1987) and Sims and Zha (2006) and during Volcker's deflation, as suggested in Friedman et al. (1996). The negative coefficient on money growth is also consistent with the findings of Canova and Menz (2011). However, the behaviour of M1 targeting during the specific period considered in this paper using new FOMC data is novel to this literature.

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 (2007). 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 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 (2007)), and never reversed (Kane (1974), Meulendyke (1988), Larkin et al. (1988) and Mishkin (2007)). 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[15] who bowed to pressure from the Congress, or inflation

[15]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

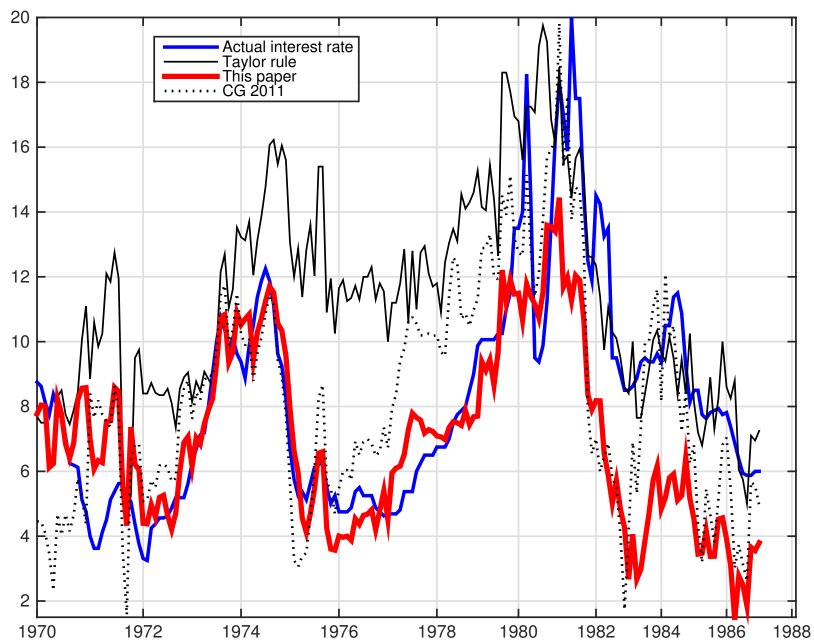
expectations became embedded so that a large interest rate hike was required but never took place. As soon as signs of a recession started building this small period of active policy was reversed in favour of passive policy (the stop phase) as documented by Goodfriend (2005).

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

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.

the baseline policy rule estimated in this paper explains interest rates better than any of the alternative policy rules during the Great Inflation. Figure 5 presents the interest rates implied by each of these specifications compared with actual interest rates from 1970 through to 1987.

Figure 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.

3.1.2. 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 introduced in section 2:[16]

$$m_t^n = c_0 + \beta_0 p_t + \beta_1 y_t + \beta_2 i_t + \tau_t \tag{21}$$

Following Ireland (2009) and Stock and Watson (1993), I use quarterly data on nominal money, M1,[17] real net national product, the six-month commercial

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

[17] 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.

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 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 2 summarizes these estimates.

Table 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 evidence 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.

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 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.[18] To identify the contribution of the two channels 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

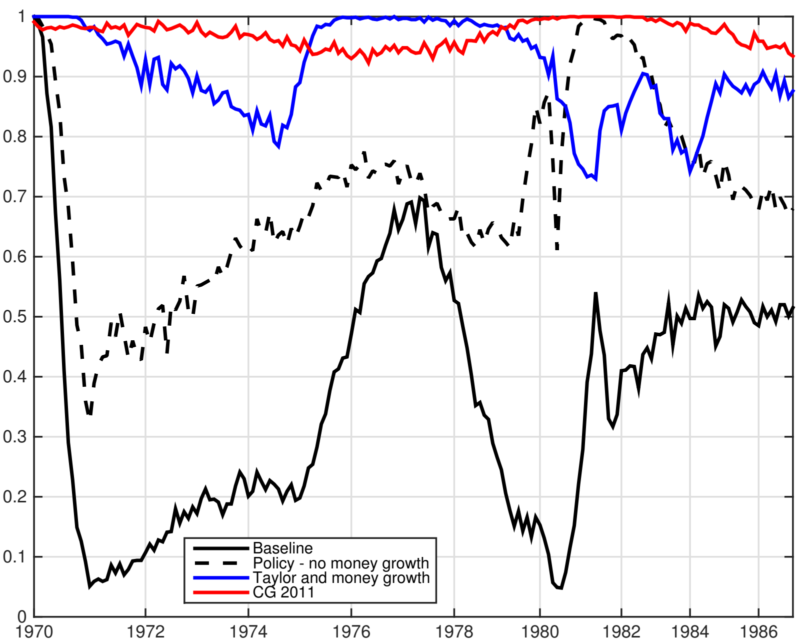
[18]A detailed discussion of this methodology is contained in Coibion and Gorodnichenko (2011) and will not be repeated here.

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.[19] 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 paper, 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.

[19] 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 6: Baseline determinacy rates

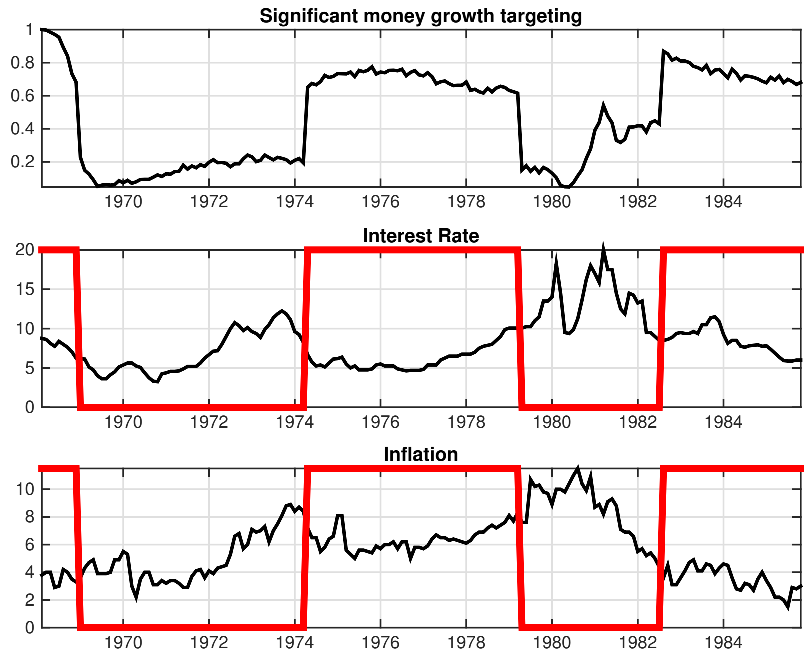


This figure plots the likelihood of determinacy under different policy rules based on the parameterized demand curve. The solid black line represents determinacy under the baseline policy parameters with money growth objectives. The dotted black line presents determinacy under the estimated policy rule, 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.[20] Based on this regime switching 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 paper, as the sufficiently weak response to money growth had a primary role in rendering policy passive, despite a sufficiently strong response to inflation.

[20] 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 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.[21] Since the relationship between nominal money and inflation is marginally weaker in the estimated money demand relationship, the indeterminacy region shrinks slightly, 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

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

to the indeterminacy 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 3.

Table 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. (1998a) 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), Bianchi (2012) and Lubik et al. (2014)). 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.

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. (1998a)).[22]

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

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 Galí (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 4 summarizes the results.

Table 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.[23] 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.[24] 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 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 just monetary growth objectives 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

[23]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.

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

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 5 summarizes these results.

Table 5: Estimate 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.

4. International Evidence of Monetary 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 paper 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.[25] Table 6 summarizes my results.

Table 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 countries. First, I find that out of the thirty-four countries in the data sam-

[25] 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.

ple, 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 paper, 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.

5. Conclusion

In this paper 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 M1 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.

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 (1987), and Sims and Zha (2006), and contribute to the findings of Benati and Mumtaz (2007), Friedman (1996), and Clarida et al. (1998b). 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. (1998a), 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 M1 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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A. For Online Publication

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*	**0.3***	**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 parentheses. 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 3: NLS/IV estimates

My TV estimates 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:

$$i_t = \rho_{1,t} i_{t-1} + \rho_{2,t} i_{t-2} + (1 - \rho_{1,t} - \rho_{2,t})[(\psi_{\pi,t} + d_{1,t})\pi_t + (\psi_{x,t} + d_{1,t})x_t + (\psi_{m,t} + d_{1,t})\Delta m_t^n] + c_t + \epsilon_t \tag{22}$$

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

Parameter	NLS (1)	NLS (2)	IV (1)	IV (2)
ψ_π	0.73^{**}	0.37^{**}	$\mathbf{0.46}$	$\mathbf{0.50}^{*}$
	(0.24)	(0.15)	$(\mathbf{0.25})$	$(\mathbf{0.24})$
ψ_x	0.23^{**}	0.33^{***}	$\mathbf{0.13}$	$\mathbf{0.39}^{*}$
	(0.10)	(0.08)	$(\mathbf{0.09})$	$(\mathbf{0.15})$
$\psi_{\Delta m}$	–	0.03	–	$\mathbf{1.06}$
	–	(0.03)	–	$(\mathbf{0.72})$
$d_{1,t}\psi_{\Delta m}$	–	-0.17^{**}	–	$\mathbf{-1.36}^{*}$
	–	(0.05)	–	$(\mathbf{0.67})$
$d_{1,t}\psi_\pi$	0.67	1.03^{*}	$\mathbf{0.41}$	$\mathbf{1.09}^{*}$
	(0.51)	(0.41)	$(\mathbf{0.41})$	$(\mathbf{0.55})$
$d_{1,t}\psi_x$	0.51	-0.001	$\mathbf{0.28}$	$\mathbf{-0.32}$
	(0.43)	(0.32)	$(\mathbf{0.35})$	$(\mathbf{0.44})$
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 parentheses. 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 condition

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

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) + g_t \tag{23}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \tag{24}$$

$$\Delta m_t = \eta_\pi \pi_t + \eta_x \Delta x_t - \eta_i \Delta i_t + \eta_x \Delta y_t^n + \tau_t \tag{25}$$

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1 - \rho_1 - \rho_2)[\psi_\pi \pi_t + \psi_x x_t + \psi_m \Delta m_t^n] + c_t + \epsilon_t \tag{26}$$

First, by substituting the money demand equation in the monetary policy rule, we can simplify the monetary policy rule and write it in the following form:

$$i_t = \delta_1 i_{t-1} + \delta_2 i_{t-2} + \delta_3 \pi_t + \delta_4 x_t + \delta_5 x_{t-1} \tag{27}$$

where:

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

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

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

We can write the model in the following compact state space form:

$$\mathbf{A} z_{t+1} = \mathbf{B} z_t + \mathbf{C} v_t \tag{28}$$

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 contain two nonpredetermined 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 $p(-1) = -1 + a_4 - a_3 + a_2 - a_1 + a_0$. This is given by the following two conditions:

$$p(1) = (\beta\sigma)^{-1}((\delta_4 + \delta_5)(1 - \beta) + \kappa(\delta_3 - 1) + (\delta_1 + \delta_2)\kappa) \tag{29}$$

$$p(-1) = -(\beta\sigma)^{-1}((\delta_4 - \delta_5)(1 + \beta) + \kappa\delta_3 + (\delta_1 - \delta_2 + 1)(\kappa + 2\sigma + 2\beta\sigma)) \tag{30}$$

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 30.

$$|(\beta\sigma)^{-1}((\delta_4 + \delta_5)(1 - \beta) + \kappa(\delta_3 - 1) + (\delta_1 + \delta_2)\kappa)| > 0 \tag{31}$$

■