An Overhaul of Fed Doctrine: Nominal Income and the Great Moderation

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Abstract

The Great Moderation is often characterized by the decline in the variability of output and inflation from earlier periods. While a multitude of explanations for the Great Moderation exist, notable research has focused on the role of monetary policy. Specifically, early evidence suggested that the increased stability has been associated with monetary policy that responded much more strongly to rising inflation. Recent evidence casts doubt on this change in monetary policy. An alternative hypothesis is that the change in monetary policy was the result of a change in doctrine; specifically the rejection of the view that inflation was largely a cost-push phenomenon. As a result, this alternative hypothesis suggests that the change in monetary policy beginning in 1979 is reflected in the Federal Reserve's response to movements in nominal income rather than inflation as previously argued. I provide evidence for this hypothesis by estimating the parameters of a monetary policy rule in which policy adjusts to forecasts of nominal GDP for the pre- and post-Volcker eras. Finally, I embed the rule in two dynamic stochastic general equilibrium models with gradual price adjustment to determine whether the overhaul of doctrine can explain the reduction in the volatility of inflation and the output gap.

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1 Introduction

Over the period beginning around 1984 through much of 2007, there was a substantial decline in macroeconomic volatility. Specifically, Blanchard and Simon (2001) have shown that the standard deviation of quarterly output growth declined by half and that of inflation declined by two-thirds over this period.[2] Given this increased stability, this time period has been characterized as "The Great Moderation."

There are three general explanations for the Great Moderation. The first view is that the moderation of economic fluctuations is the result of inventory dynamics (McCarthy and Rakrajsek, 2007).[3] An alternate view presented by Stock and Watson (2003) is that the increased stability is the result of smaller macroeconomic shocks. Finally, others such as Taylor (1999), Clarida, Gali, and Gertler (2000), and Bernanke (2004) have attributed this decline in the United States to a significant change in monetary policy. Specifically, these authors argue that monetary policy after the appointment of Paul Volcker to the Federal Reserve is characterized by an increased responsiveness of monetary policy to inflation. A series of work by Orphanides (2001, 2002, 2003c, 2004) casts doubt on these results.

In reality, an explanation of the Great Moderation likely requires some degree of each hypothesis. Nevertheless, if any part of the decline in volatility can be attributed to monetary policy, it is important to understand precisely the change in policy to ensure that past mistakes are not repeated. The purpose of this paper is to present an alternative perspective to the earlier work on monetary policy and the Great Moderation that views the changes in policy as the result an overhaul of Federal Reserve doctrine rather than as a change in the parameters of the Taylor rule. Specifically, this paper provides empirical support for a view put forth by Nelson (2005), Hetzel (2008a, 2008b), and Dicecio and Nelson (2009) that the change in monetary policy beginning with Paul Volcker represented an overhaul of the previous doctrine that largely viewed inflation as a cost-push phenomenon.

[2]This change was also noted earlier by McConnell and Perez-Quiros (2000) and Kim and Nelson (1999).

[3]The authors acknowledge that changes in monetary policy are likely to have played a significant role as well.

The paper proceeds as follows. Section 2 presents two views of monetary policy that can potentially explain the Great Moderation. The first view emphasizes the increased emphasis of the Federal Reserve to the inflation rate. The second view emphasizes an overhaul of the doctrine within the Federal Reserve in which the central bank changed its beliefs about the underlying causes of inflation. Specifically, this overhaul can be reflected in the Federal Reserve's responsiveness to its forecast of nominal income growth rather than that of the inflation rate. Section 3 provides empirical support to the alternative hypothesis. Section 4 examines the macroeconomic implications of the shift in policy and section 5 concludes.

2 Two Stories of Macroeconomic Stability

2.1 Monetary Policy and the Great Moderation

Evaluation of monetary policy and the Great Moderation often begin with a description of the Taylor curve, shown in Figure 1. The Taylor curve is an efficiency locus for monetary policy that describes the trade-off between the variability of inflation and the variability of output.[4] Assuming that monetary policy is optimal, the Taylor curve suggests that policymakers can only cause movements along the curve. By contrast, shifts in the curve result from structural changes in the economy. Thus, for monetary policy to explain the Great Moderation, it must be true that monetary policy was not optimal (operating beyond the Taylor curve, as shown by point A). It follows that in order to explain a potential role for monetary policy in the Great Moderation, one must be able to show a sizable shift in policy.

Historical analysis of monetary policy has provided some evidence for the conjecture that policy was not optimal. Following Taylor (1993), this research has emphasized a monetary policy rule in which the Federal Reserve adjusts the federal funds rate in response to inflation and economic activity commonly known as the Taylor rule. The adoption of the framework has been aided by ability of this rule to capture the historical behavior of monetary policy

[4]For a discussion of the Taylor curve, see Taylor (1998). Examples of analyses of the Great Moderation that focus on the Taylor curve, see Stock and Watson (2003) and Bernanke (2004).

quite well (Taylor, 1993; Orphanides, 2003a). In addition, such analysis generally identifies the shift in policy that could potentially explain the Great Moderation coincides with the appointment of Paul Volcker to the Federal Reserve in October 1979 as a result of the significant and lasting reduction in inflation since the start of his tenure.

Taylor (1999) conducts an historical analysis for the era of the international gold standard and the period after World War II. His analysis aims to measure the particular response of the federal funds rate characterized by the Taylor rule:

$$R_t = \bar{r}_t + \pi_t + \phi_\pi(\pi_t - \pi_t^*) + \phi_y \tilde{y} + e_t$$

where $\bar{r}$ is the real rate of interest, π is the inflation rate, π^* is the target rate of inflation, and $\tilde{y}$ is the output gap. The coefficient estimates given by Taylor for this model are shown in Table 1.

Taylor's coefficient estimates show a clear shift in policy between the pre-1979 era and the era in which Alan Greenspan oversaw the Federal Reserve. For the period prior to 1979, the coefficient on inflation is nearly half and that on output is one-third of those estimated for the Greenspan era. What's more, the latter results are also consistent with the normative suggestions given by Taylor (1993).

Particularly important to Taylor's analysis is the fact that the response of the federal funds rate to inflation in the pre-1979 period is less than unity. As Taylor emphasizes, this tepid response to rising inflation implies that when the inflation rate rises, the real interest rate declines. The decline in the real interest rate stimulates aggregate demand and stokes further inflationary pressures. This type of policy leads to instability as inflation is able to increase without bound. By contrast, if the coefficient on inflation is greater than unity, an increase in inflation will result in an increase in the real interest rate and would generate stability. Thus, the shift in policy from the Great Inflation of the late 1960s and 1970s to that of the Great Moderation is a more aggressive response to inflation. Specifically, monetary policy in the latter period is one in which the real interest rate increases in response to rising inflation.

A similar analysis to that of Taylor is undertaken by Clarida, Gali, and Gertler (2000). This latter analysis, however, differs in two important respects. First, one common criticism of the Taylor rule is that policy decisions require access to contemporaneous data.[5] As emphasized in McCallum and Nelson (1999a: 18), rules that require knowledge of contemporaneous data are non-operational because "there is uncertainty regarding the realized value of real GDP even at the end of the quarter in actual economies." To overcome this problem, Clarida, et. al posit a forward-looking rule in which the central bank responds to deviations of expected inflation and output from their respective targets. The second difference from the earlier analysis stems from the fact that the basic Taylor rule seems much too crude to fully capture the actual behavior of the federal funds rates in that it ignores the Federal Reserve's tendency to smooth interest rates over time.[6] Thus, while the long run behavior of the central bank can be considered to be consistent with the Taylor rule, the behavior of the federal funds rate can be characterized as follows:

$$R_t = \rho R_{t-1} + (1-\rho)[\bar{r}_t + \pi_t + \phi_\pi(\pi_t - \pi_t^*) + \phi_y \tilde{y}] + \eta_t$$

where monetary policy gradually moves toward its long run target.

As shown in Table 1, the estimation results corresponding to this model highlight a clear shift in monetary policy after 1979. Consistent with the results given by Taylor, the magnitude of the estimated coefficients on inflation and the output gap each increased in the post-Volcker era. Specifically, the coefficient on inflation is two-and-a-half times larger and the coefficient on the output gap is over three times as large as the corresponding estimates from the earlier period. What's more, the response of the Federal Reserve to inflation in the pre-Volcker era is again insufficient to increase the real interest rate.

The differences in policy have important implications for macroeconomic dynamics as the authors find that when using the monetary policy rule outlined above in a standard New Keynesian model, the estimated rule from the earlier period results in an indeterminacy

[5]It should be noted that the original Taylor rule (Taylor, 1993) related the interest rate instrument with *lagged* values of inflation and the output gap.

[6]For a discussion of theoretical justifications for interest rate smoothing see Sack and Wieland (2000).

Table 1: Estimated Taylor Rules

	Coefficient on:		
	π	$\tilde{y}$	R_{t-1}
Taylor			
1960 - 1979	0.81	0.25	
1987 - 1997	1.53	0.77	
Clarida, Gali, Gertler			
1960 - 1979	0.83	0.27	0.68
1979 - 1996	2.15	0.93	0.79
Orphanides			
1966 - 1979	1.49	0.46	0.68
1979 - 1995	1.89	0.18	0.77

Clarida, Gali and Gertler as well as Orphanides estimate the Taylor rule with an autoregressive component, ρ, to capture interest rate smoothing evident in policy.

of equilibrium. They argue that the indeterminacy results from the insufficient response of the central bank to higher rates of inflation. In this case, shocks that are not related to economic fundamentals can cause increases in prices. In other words, the existence of multiple equilibria is the result of the potential for self-fulfilling expectations. When coupled with the weak response of monetary policy to changes in inflation, large shocks can have a significant impact on the the volatility of output and prices.[7]

Finally, Clarida, et. al show that the volatility of inflation and output varies inversely with the magnitude of the coefficient on inflation. In fact, when the coefficient on inflation rises from one to two, the volatility of inflation and output decline by more than half. This provides further evidence that the shift in policy beginning in 1979 can indeed explain the sizable declines in volatility experienced during the Great Moderation.

A recent series of research by Orphanides (2001, 2002, 2003c, 2004), however, calls into question the shift in how monetary policy responds to inflation. Orphanides (2002) shows that, when using data available to policymakers in real-time, monetary policy during the

[7]Note that indeterminacy is different than the instability argument put forth by Taylor. In this case, the equilibria are stable.

1970s was characterized by a rule that is consistent with the estimated rules for the period after 1979. The distinction between using ex post data and data that is available in real-time is important because there is often considerable noise in variables in real-time. What's more, macroeconomic aggregates often undergo significant revisions in the aftermath of their release. In order to capture the actual intent of the policy, one must rely upon data or forecasts that were available at the time the decision was made.

In a more comprehensive analysis, Orphanides (2004) estimates the Taylor rule given in Clarida, Gali, and Gertler (2000) for the periods 1966 - 1979 and 1979 - 1995 using the Greenbook forecasts from the Federal Reserve. The results are shown in Table 1.[8] These results show two clear differences between those of Taylor (1999) and Clarida, Gali, and Gertler (2000). First, the response parameter to inflation is greater than unity in each time period. These results cast serious doubts on the explanations of both an unstable equilibrium and the existence of sunspot equilibria highlighted in the earlier work. Second, for the period after 1979, the response parameter to the output gap is noticeably smaller when estimated using real-time data. Thus, while the results of Taylor and Clarida, et. al suggest that the Federal Reserve became more activist toward the output gap, Orphanides's results imply a more tepid response.

Overall, the results of Orphanides (2004) demonstrate a policy that seems quite consistent over each period. In fact, the one exception is the decline in the response to the output gap. This would seem to imply that any success of post-1979 policy is due to the decline in the response to the output gap from the earlier period. Again, this runs counter to hypothesis that the success of the Federal Reserve was due to the increased responsiveness to inflation.

2.2 An Alternative Perspective

The view held by Taylor and Clarida, et. al is broadly defined as one in which the Federal Reserve did not have a strong enough response to inflation. There are a wide variety of

[8]Orphanides estimates these rules over various forecast time horizons. The results are robust to the alternative specifications.

reasons why this might be the case. For example, DeLong (1997) argues that the Fed's stronger commitment was reduce unemployment. Clarida, et. al argue that Federal Reserve served to accommodate higher inflation expectations. Similarly, Christiano and Gust (2000) argue that the central bank simply responded to non-monetary shocks with expansionary policy. Finally, Taylor (1992) suggests that the Fed underestimated the costs of inflation.

There are substantial reasons to doubt each of these hypotheses. For example, the work of Barsky and Killian (2001) suggests that the monetary policy expansion started *before* the non-monetary events and that rising commodity prices were the result, not the cause, of policy easing. This would seem to cast doubt on the views put forth by Clarida et. al and Christiano and Gust. What's more, the view that inflation was somehow of lesser concern to the Federal Reserve during the late 1960s and 1970s is similarly not supported by the views of the policymakers themselves. For example, Hetzel (1998: 21) notes that Arthur Burns, Federal Reserve chairman throughout much of the 1970s, "was fiercely opposed to inflation." In addition, the views of Taylor (1992) and DeLong (1997) require that the Fed had a belief in a permanent trade-off between inflation and unemployment. In other words, this view implies that the Federal Reserve deliberately created inflation to lower unemployment. However, in a variety of public statements Arthur Burns explicitly rejected this notion (Dicecio and Nelson, 2009). Statements by others within the Federal Reserve at the time also confirmed the view that the long run Phillips curve was vertical (Meltzer, 2010). When taken together with the work of Orphanides discussed above, it would seem that the change in Federal Reserve policy was not summarized by an adjustment of the weights on inflation and unemployment (or the output gap) in a Taylor-type rule.

An alternative view of the change in monetary policy from the Great Inflation to the Great Moderation is that there was an overhaul of Federal Reserve doctrine. Beginning in the late 1960s and throughout the 1970s, the emerging view was that inflation was a cost-push, and therefore non-monetary, phenomenon. This was increasingly reflected in views expressed in newspaper columns, statements by politicians, and most importantly within the Federal Reserve (Nelson, 2005). Hetzel (2008b: 161) notes that the "Keynesian orthodoxy

held that the optimal combination of fiscal and monetary policy could deliver sustained real growth and high output while incomes policies could limit the resulting inflation."[9] As early as 1970, Federal Reserve chairman Arthur Burns argued that "monetary and fiscal tools are inadequate for dealing with sources of price inflation such as are plaguing us now – that is, pressure on the costs arising from excessive wage increases" (quoted in Nelson, 2005: 17). What's more, Meltzer (2009: 15) argues that Burns often "blamed inflation on labor unions, monopolies, and the welfare state." Each of which could be interpreted as cost-push shocks. Further, as Nelson (2005) points out, Burns routinely denied any role of the Federal Reserve in generating inflation and repeatedly argued against a tighter monetary policy.

The idea that the Fed was using an incorrect doctrine was recognized early by Friedman (1972: 13) who noted that the "failure of monetary policy ... has scientific interest because the erratic and destabilizing monetary policy has largely resulted from acceptance of erroneous economic theories." He concluded that "monetary policy did not fail in the past three years in the relevant scientific sense. The drugs produced the effect to be expected though the wrong drug was administered" (ibid: 17). Friedman's statements were motivated by then-recent remarks by Arthur Burns that "the rules of economics are not working in quite the way they used to" (ibid: 11) with regards to inflation.

When viewed in an aggregate demand (AD)-aggregate supply (AS) framework, the cost-push view coupled with the persistently overestimated negative output gaps shown by Orphanides (2004) suggest that the Federal Reserve erroneously interpreted positive AD shocks as negative AS shocks. What's more, given the belief within the Federal Reserve that its ability to correct inflationary forces was limited, the central bank would likely respond to these misinterpreted shocks with either a tepid response or, worse yet, expansionary policy while advocating wage and price controls. In point of fact, the latter was precisely the policy advocated by Arthur Burns and later the Nixon administration (Hetzel, 1998). This view was similarly supported by Burn's replacement G. William Miller in 1978 (Nelson, 2005;

[9]The term "incomes policy" refers to some type of wage and price controls. For a sample of the "Keynesian orthodoxy" see Samuelson and Solow (1960).

Dicecio and Nelson, 2009).

An expansionary monetary policy (an increase in AD) could be rationalized by those who favored the cost-push view because they denied "that upward shifts of output *toward* potential were a source of inflationary pressure" (Nelson, 2004: 20; emphasis in the original). This view is illustrated in Figure 2, which depicts the typical AD-AS graph with the notable difference being the shape of the short-run aggregate supply (SAS) curve. The cost-push view, as advocated by policymakers in the 1970s, suggests that the SAS curve is horizontal when output is below potential. The implication of this characteristic is that cost-push shocks could drive prices higher and output lower. Meanwhile, monetary policy could successfully increase AD without generating inflationary pressures. On the contrary, under this view, "a markedly more restrictive policy would have led to a still sharper rise in interest rates and risked a premature ending of the business expansion, without limiting to any significant degree this years upsurge of the price level" (Burns, 1973: 21). The effect of expansionary policy under this framework is illustrated in Panel B of Figure 2.

This view can also explain why there are observed differences in the estimates of the parameter on inflation in the Taylor rule from the Great Inflation to the Great Moderation. Under the cost-push doctrine, a forecast based on the Phillips curve would result in systematically lower predicted values of inflation. This is precisely the empirically reality observed by Orphanides (2002). What's more, the fact that inflation was systematically under-forecast implies that estimates of the Federal Reserve's reaction function, as measured by the Taylor rule, would imply that the central bank had a much stronger responsiveness to inflation when measured by the forecast rather than its ex post value.[10]

This viewpoint changed with the appointment of Paul Volcker to Federal Reserve chairman. Following his appointment as Fed chairman, Volcker elevated inflation reduction as the top priority of the FOMC, specifically through an emphasis on inflation expectations (Hetzel, 2008a; Meltzer, 2009, 2010). As Hetzel (2008a: 150) notes, "Volcker challenged

[10]Meltzer (2009) notes that both Volcker and Greenspan had little use for the Federal Reserve staff forecasts of inflation based on the Phillips curve.

Keynesian orthodoxy, which held that the 'high' unemployment of the 1970s demonstrated that inflation arose from cost-push and supply shocks." In direct contrast to policies during the Great Inflation, Volcker argued that the policy adopted by the FOMC "rests on a simple premise – one documented by centuries of experience – that the inflationary process is ultimately related to excessive growth in money and credit" (quoted in Hetzel, 2008a: 151). This view implicitly accepts that rising inflation is caused by demand-pull, or excess aggregate demand.

The distinction between the interpretation of the shocks is particularly important for understanding the potential change in monetary policy from an overhaul of doctrine. An AD shock is associated with rising output and increasing prices. This implies that AD shocks are associated with increases in nominal income growth. By contrast, AS shocks are characterized by opposite movements in prices and output and should therefore result in a negligible impact on nominal income growth. As a result, misperceptions about the nature of the shock can lead to persistent increases in AD and therefore rising rates of nominal income growth. A recognition that rising inflation is the result of increases in AD, however, would result in corresponding reductions in AD induced by monetary policy. It follows that an alternative assessment of the change of monetary policy from the pre- to post-Volcker era is to determine its role in stabilizing nominal income growth. An increased responsiveness of monetary policy to nominal income growth would therefore provide empirical support for the overhaul of doctrine hypothesis.

3 Empirical Evidence

A cursory examination of the period labeled the Great Moderation demonstrates that the period is not only one of moderation in the volatility of real output and inflation, but also of nominal spending. The behavior of the growth of nominal spending over the last 50 years in the United States is shown in Figure 3. The time period classified as the Great Moderation is characterized by stability in the growth rate of nominal spending. By contrast, the period of

the late 1960s and 1970s demonstrates a clear upward trend in nominal spending, reflecting the significant increases in the inflation rate and, potentially, the persistent increases in AD as a result of misperceptions about the nature of the shock.

One way to test the hypothesis is through the use of a historical analysis of monetary policy based on a nominal spending target rule analogous to the aforementioned research on the Taylor rule. The hypothesis that monetary policy has become more responsive to changes in nominal income can assessed by estimating the following regression for the pre- and post-Volcker era:[11]

$$R_t^* = \alpha + \beta E_{t-1}\Delta x_t \tag{1}$$

where R_t^* is the long run target of the federal funds rate, $E_{t-1}\Delta x_t$ is the forecast of nominal spending for period t at the beginning of the period. Thus, while it was clearly not an explicit goal of the Federal Reserve to stabilize nominal spending, this empirical analysis examines whether the responsiveness of monetary policy to nominal income growth changed as implied by the overhaul of doctrine.

Nevertheless, even if the monetary policy rule outlined in equation (1) is consistent with how the target of the federal funds rate is determined, it is unlikely to capture the actual behavior of the federal funds rate itself over the time period in question. As previously mentioned, the Federal Reserve tends to smooth the interest rate. As a result, the federal funds rate is modeled to be consistent with Clarida, et. al:

$$R_t = \rho R_{t-1} + (1-\rho)R_t^* + \varepsilon_t \tag{2}$$

where R_t is the actual federal funds rate and R_t^* is the long run response of the federal funds rate as modeled in equation (1). The actual behavior of the federal funds rate is therefore

[11] Formally, this rule could be expressed as follows: $R_t = \bar{R} + \beta(\Delta x_t - \Delta x^*)$ where $\bar{R}$ is the desired nominal interest rate and Δx^* is the nominal income growth target. It follows that the constant term is given by $\alpha = \bar{R} - \beta\Delta x^*$.

Table 2: Smoothing Rule Results

Time Period	$\tilde{\alpha}$	$\tilde{\beta}$	ρ
1966:I - 1979:III	0.18 (0.77)	0.11 (0.04)	0.86 (0.10)
1979:IV - 2003:IV	-0.67 (0.42)	0.41 (0.14)	0.77 (0.09)
1966:I - 2003:IV	-0.49 (0.30)	0.17 (0.05)	0.91 (0.03)

This corresponds to the rule $R_t = \rho R_{t-1} + \tilde{\alpha} + \tilde{\beta}\Delta x_t + \varepsilon_t$ where $\tilde{\alpha} = (1-\rho)\alpha$ and $\tilde{\beta} = (1-\rho)\beta$

captured by substituting equation (1) into equation (2) such that:[12]

$$R_t = \rho R_{t-1} + (1-\rho)(\alpha + \beta E_{t-1}\Delta x_t) + \varepsilon_t \tag{3}$$

In order to examine the responsiveness of the Federal Reserve to nominal spending, I estimate equation (3) for the pre- and post-Volcker eras. Expected nominal GDP growth is given by the quarter-to-quarter Greenbook forecast expressed in annual rates thereby assuring that the rule is estimated with data available to the FOMC at the time policy was made. The results are shown in Table 2.

Before discussing the results, a note about the estimation seems prudent. When the model is estimated using least squares, there is some evidence of serial correlation in the error term. In order to accurately evaluate and examine the robustness of the results, two techniques are used. In the first method, the parameters are estimated using least squares and evaluated for significance using Newey-West standard errors that are robust to serial correlation. The second method uses a vector of instruments to estimate the parameters using Generalized Method of Moments with a spectral density matrix that accounts for serial correlation. Each of the techniques produced similar results. The least squares estimates are given in the corresponding table with the Newey-West standard errors in parentheses.

As shown in Table 2, there is a sizable difference in the response of both the federal funds rate and the implied long run response of the federal funds rate to a change in nominal GDP. Forecasts of nominal GDP have a positive and significant impact on the actual federal

[12]A similar equation is estimated by McCallum and Nelson (1999b) for the period 1979 - 1997. However, their estimates are calculated using ex post data and thus succumb to the same criticism outlined above.

funds rate in both the pre- and post-Volcker era. However, this effect is 4 times smaller in the pre-Volcker era than that of the post-1979. In addition, the estimates suggest that the long-run response of the federal funds rate for each period is given by the following:[13]

$$R_t^* = .79\Delta x_t \tag{4}$$

$$R_t^* = 1.78\Delta x_t \tag{5}$$

where equations (4) and (5) represent the pre- and post-Volcker eras, respectively. These results bear some similarity to those of Taylor and Clarida, et. al regarding the Federal Reserve's response to nominal variables. In this earlier work, a coefficient on inflation less than unity implies that that the real interest rate falls when inflation rises creating the potential for instability or sunspot equilibria. By contrast, this model suggests an eerily similar increased responsiveness to nominal income. Given that the results of this earlier work are not robust to estimation using real-time data, the results presented here suggest that policy was indeed much more tepid to a nominal variable in the pre-Volcker era, albeit one different than previously suggested. The macroeconomic implications of the policy shift are considered below.

4 Nominal Income Responsiveness and Volatility

Despite empirical evidence that the response of the federal funds rate to the Greenbook forecast of nominal income was stronger in the post-Volcker era than in the preceding period, it does not offer any conclusions regarding volatility. In an attempt to examine macroeconomic implications, I embed the rule in two DSGE models and compare the implications under the alternative parameter estimates for each period. The first model is the standard New Keynesian model with Calvo price adjustment.[14] The second model is the semi-classical P-bar model, in which prices are fixed at the beginning of each period and the natural rate

[13]The variables included in the target are only those in which the corresponding parameters are statistically significantly different from zero in estimation.

[14]For a textbook treatment, see Gali (2008) or Woodford (2003).

hypothesis is satisfied.[15] The choice of these models is motivated by their ability to capture the empirical properties of the business cycle reasonably well. Two models are employed to examine the robustness of the results to different structural specifications.

4.1 Framework for Analysis

The equilibrium of the standard New Keynesian model consists of the following log-linear equations:

$$y_t^n = \phi_{ya}^n a_t \tag{6}$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi_{t+1}) + e_t^{IS} \tag{7}$$

$$\tilde{y}_t = y_t - y_t^n \tag{8}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \tilde{y}_t \tag{9}$$

$$a_t = \rho_a a_{t-1} + e_t^a \tag{10}$$

where y_t^n is the natural rate of output, a_t is a technology shock, y_t is real output, $\tilde{y}_t$ is the output gap, and π_t is the inflation rate.

The equilibrium of the P-bar model is given by the following log-linear equations:

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - b(r_t - E_t \pi_{t+1}) + e_t^{IS} \tag{11}$$

$$E_{t-1} \tilde{y}_t = \phi \tilde{y}_{t-1} \tag{12}$$

$$\tilde{y}_t = y_t - \bar{y}_t \tag{13}$$

$$\bar{y}_t = \rho_y \bar{y}_{t-1} + e_t^y \tag{14}$$

where $\bar{y}$ is the natural rate of output.

Here, equations (7) and (11) are dynamic, forward-looking IS equations. Equations (8) and (13) define the output gap. Equation (6) defines the natural rate of output. In the P-bar model, the natural rate is assumed to follow an AR(1) process as shown in (14). Equations

[15] For a discussion of this model, see McCallum and Nelson (1999a) and McCallum (2008). As is pointed out in McCallum (2008), the natural rate hypothesis is not satisfied in other models of gradual price adjustment.

(9) and (12) capture the price adjustment process in each model, with the former being the New Keynesian Phillips curve.[16]

Monetary policy is conducted using the following interest rate rule, expressed in log-deviations:

$$r_t = \rho_r r_{t-1} + (1 - \rho_r)\beta \Delta x_t + e_t^r$$

where $(1-\rho_r)\beta$ corresponds to the estimates of $\tilde{\beta}$ above. Together with an identity for nominal income, these equations are sufficient to solve for the equilibrium for the corresponding model.

4.2 Simulation Results

The model is calibrated using standard values in the literature. The discount factor, β, is set equal to 0.99. Consistent with Gali (2008) and McCallum (2008), $\frac{1}{\sigma} = b = 1$. Following McCallum, the autoregressive parameter in equation (12) is set to 0.89. Also, following Gali (2008), the parameters ϕ_{ya}^n and κ are set to 1 and 0.3, respectively. The monetary policy shock, e_t^r is assumed to be white noise with standard deviation of 0.002. The IS shock, e_t^{IS}, is also white noise with standard deviation of 0.01.[17] The technology shock, e_t^y in the P-bar model and e_t^a for the New Keynesian model, has a standard deviation of 0.007 and the autoregressive coefficient on the technology shock, ρ_y and ρ_a, is 0.95. These values are consistent with those reported in the real business cycle literature. Each model is solved using the solution algorithm given by King and Watson (2002).

The objective of the simulations is two-fold. First, alternative rules might have different implications for the equilibrium of the model. In forward-looking rational expectations models it is possible for there to exist an infinite number of equilibria resulting from the behavior of monetary policy. Although these equilibria are locally stable, they do create

[16] Equation (12) captures price adjustment in the sense that the minimal state variable solution allows one to express $E_{t-1}p_t = \phi p_{t-1}$ as $E_{t-1}\tilde{y}_t = \phi \tilde{y}_{t-1}$. See McCallum and Nelson (1999a) or McCallum (2008) for further explanation.

[17] These match those estimated in McCallum and Nelson (1999a).

the potential for economic fluctuations driven by expectations that are not correlated with economic fundamentals. Such shocks are problematic because they increase volatility and thus, assuming agents are risk averse, reduce welfare. Second, a major characteristic of the Great Moderation is the reduction in the volatility of inflation and output. Thus, these simulations can provide insight into whether a stronger response of monetary policy to changes in nominal income can explain the reductions in volatility. The results are discussed in turn below.

4.2.1 Sunspots and Indeterminacy

It has become standard knowledge in the literature that the parameters of the policy are important to the determination of equilibrium in dynamic, forward-looking rational expectations models. Bernanke and Woodford (1997) and Clarida, Gali, and Gertler (1999) highlight the fact that a coefficient on inflation in the policy rule that is less than unity causes indeterminacy of equilibrium. In this case sunspot shocks, or shocks that are uncorrelated with economic fundamentals, can cause self-fulfilling fluctuations in the economy. As previously mentioned, this can be understood intuitively as resulting from the failure of the central bank to sufficiently respond to rising inflation. In this case, rising inflation is associated with a decline in the real interest rate, which in turn increases aggregate demand and heightens inflationary pressures.

A monetary policy rule that insufficiently responded to deviations of nominal income growth from its target rate would similarly be susceptible to self-fulfilling fluctuations. Under a nominal income target, aggregate supply shocks would result in little or no response of monetary policy as movements in prices would offset, in whole or in part, movements in output. However, fluctuations in aggregate demand result in the co-movement of output and prices. It follows that an insufficient response to changes in nominal income correspond to an insufficient response to aggregate demand shocks.

Simulations of each model produce a unique equilibrium result for the rule estimated for the post-Volcker era. However, simulations for the rule estimated for the earlier period

Table 3: Volatility (Nominal Income Rule)

	β	σ_π	$\sigma_{\tilde{y}}$
New Keynesian Model	1.01	0.83	1.53
	1.78	0.50	1.03
	2.00	0.46	0.97
P-Par Model	1.15	3.29	11.12
	1.78	1.75	4.73
	2.00	1.61	4.27

produce an indeterminacy of equilibrium. Taken together with the estimates of the Taylor rule using real time data that show that the coefficient on inflation was greater than unity in each period, these results would seem to suggest that it was the Federal Reserve's failure to sufficiently respond to nominal income rather than inflation that explains the indeterminacy result.[18]

4.2.2 Implications Under Alternate Rules

The final issue to examine is whether or not an increased responsiveness to changes in nominal income can explain the reductions in the volatility of output and inflation. The standard deviations of the output gap and inflation for different parameter estimates are given in Table 3 and expressed as percentages.

The results shown in Table 3 show clear and sizable reductions the volatility of inflation and the output gap as the size of the response to changes in nominal income become larger. In the New Keynesian model a doubling of the parameter β from near unity to two results in a decline in the volatility of the output gap of one-third and a reduction in the volatility of inflation of nearly one-half. In the P-bar model, an increase in the coefficient on the growth

[18]It is important to note that the indeterminacy results from the fact that the models employed in this paper are forward-looking rational expectations models. If these models were backward-looking, the type of monetary policy used in the pre-1979 period would result in instability.

of nominal income from 1.15 to 2 leads to a decline in the volatility of output by over one-half and a decline in the volatility of inflation by approximately one-half.[19] For each model, when the value of the coefficient on nominal income in the long run target is less than or equal to unity, an indeterminacy of equilibrium results thereby explaining the results of the previous subsection.

These results give further credence to the importance of the increased responsiveness of the Federal Reserve to nominal income growth in the period after 1979. The tepid response to nominal income that characterized the earlier period created the potential for self-fulfilling fluctuations in inflation and output. What's more, there is reason to believe that the increased responsiveness in the latter period not only stabilized nominal income growth, but also led to reductions in the volatility of inflation and output. Finally, these results are robust to model specification.

5 Conclusion

Given the reductions in the volatility of output and inflation during the Great Moderation, it is important to consider whether these reductions can be attributed to policy. The work of Taylor (1999) and Clarida, Gali, and Gertler (2000) suggests that in the period following the appointment of Paul Volcker to the Federal Reserve was characterized by an increased response of monetary policy to inflation. Recent research has cast doubt on this conclusion by showing that when estimating a Taylor rule using real time data, the Federal Reserve's reaction to inflation during the Great Inflation was quite similar to that followed in the years after Volcker's appointment.

This paper presents an alternate view that emphasizes the overhaul of Federal Reserve doctrine from the Great Inflation to the Great Moderation. Specifically, during the late 1960s and 1970s the Federal Reserve operated under the belief that inflation was largely driven by cost-push forces and the parameter on the output gap in the Phillips curve was

[19]The value of 1.15 is chosen because volatility increases considerably as β approaches unity.

only positive when the output gap was positive. What's more, it was argued that this view can be understood by examining the Federal Reserve's responsiveness to nominal income growth.

Empirical evidence presented in this paper supports the view that the Federal Reserve increased its responsiveness to the growth rate of nominal spending and thus that the change in policy was a change in Fed doctrine. Unlike the earlier research, these models are estimated using the Greenbook forecasts of the Federal Reserve and therefore are able to capture the actual intent of policy and are not biased by ex post data revisions. What's more, using estimated nominal income targeting models for the pre- and post-Volcker eras, this paper presents evidence that the responsiveness of the Federal Reserve to changes in nominal income growth in the earlier period was insufficient to offset shifts in aggregate demand thereby resulting in a potential for self-fulfilling expectations. In addition, it was shown that an increased responsiveness of monetary policy to nominal income growth can reduce the volatility of inflation and output. This research therefore suggests that the Great Moderation can be explained, at least in part, by an increased responsiveness of monetary policy to nominal income growth and an overhaul of Federal Reserve doctrine.

References

[1] Barsky, Robert B., and Lutz Kilian. 2001. Do We Really Know That Oil Caused the Great Stagflation? A Monetary Alternative. *NBER Macroeconomics Annual*, Vol. 16, No. 1, p. 137?183.

[2] Bernanke, Ben S. 2004. "The Great Moderation." Remarks at the Eastern Economic Association Meetings, February 20.

[3] Bernanke, Ben S. and Michael Woodford. 1997. "Inflation Forecasts and Monetary Policy." *Journal of Money, Credit, and Banking*, Vol. 25, p. 653 - 684.

[4] Blanchard, Olivier and John Simon. 2001. "The Long and Large Decline in U.S. Output Volatility." *Brookings Papers on Economic Activity*, p. 135 - 164.

[5] Burns, Arthur. 1973. "Letter on Monetary Policy." *St. Louis Federal Reserve Review*, November 1973, p. 15 - 22.

[6] Christiano, Lawrence J., and Christopher Gust. 2000. The Expectations Trap Hypothesis, *Federal Reserve Bank of Chicago Economic Perspectives*, Vol. 24, No. 2, p. 21?39.

[7] Clarida, Richard, Jordi Gali, and Mark Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature*, Vol. 37, p. 1661 - 1707.

[8] Clarida, Richard, Jordi Gali, and Mark Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics*, Vol. 115, p. 147 - 180.

[9] DeLong, J. Bradford. 1997. Americas Peacetime Inflation: The 1970s. In C.D. Romer and D.H. Romer (eds.), *Reducing Inflation: Motivation and Strategy.* Chicago: University of Chicago Press, p. 247276.

[10] Dicecio, Riccardo and Edward Nelson. 2009. "The Great Inflation in the United States and the United Kingdom: Reconciling Policy Decisions and Data Outcomes." NBER Working Paper No. 14895.

[11] Friedman, Milton. 1972. Have Monetary Policies Failed? *American Economic Review Papers and Proceedings*, Vol. 62, No. 2, p. 11?18.

[12] Gali, Jordi. 2008. *Monetary Policy, Inflation, and the Business Cycle.* Princeton: Princeton University Press.

[13] Hetzel, Robert L. 1998. "Arthur Burns and Inflation." *Federal Reserve Bank of Richmond Economic Quarterly*, Vol. 84, No. 1, p. 21 - 44.

[14] Hetzel, Robert L. 2008a. *The Monetary Policy of the Federal Reserve: A History.* Cambridge: Cambridge University Press.

[15] Hetzel, Robert L. 2008b. "What is the Monetary Standard, Or, How Did the Volcker-Greenspan FOMCs Tame Inflation?" *Federal Reserve Bank of Richmond Economic Quarterly*, Vol. 94, No. 2, p. 147 - 171.

[16] Kim, Chang-Jin and Charles Nelson. 1999. "Has the U.S. Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle." *Review of Economics and Statistics*, Vol. 81, p. 608 - 616.

[17] King, Robert G. and Mark W. Watson. 2002. "System Reduction and Solution Algorithms for Singular Linear Difference Systems under Rational Expectations." *Computational Economics*, Vol. 20, p. 57 - 86.

[18] McCallum, Bennett T. 2008. "Reconsideration of the P-bar Model of Gradual Price Adjustment." *European Economic Review*, Vol. 52, p. 1480 - 1493.

[19] McCallum, Bennett T. and Edward Nelson. 1999a. "Perfomance of Operational Policy Rules in an Estimated Semi-classical Structural Model." In John B. Taylor (ed.) *Monetary Policy Rules.* Chicago: University of Chicago.

[20] McCallum, Bennett T. and Edward Nelson. 1999b. "Nominal Income Targeting in an Open-Economy Optimizing Model." *Journal of Monetary Economics*, Vol. 43, p. 553 - 578.

[21] McCarthy, Jonathan and Egon Zakrajsek. 2007. "Inventory Dynamics and Business Cycles: What Has Changed?" *Journal of Money, Credit, and Banking*, Vol. 39, No. 2-3, p. 591 - 613.

[22] McConnell, Margaret and Gabriel Perez-Quiros. 2000. "Output Fluctuations in the United States: What Has Change Since the Early 1980s?" *American Economic Review*, Vol. 90, p. 1464 - 1476.

[23] Meltzer, Allan M. 2009. "Learning About Policy From Federal Reserve History." Keynote Address, Cato Monetary Conference, 2009.

[24] Meltzer, Allan M. 2010. *A History of the Federal Reserve, Volume 2, Book 2, 1970-1986*. Chicago: University of Chicago Press.

[25] Nelson, Edward. 2005. The Great Inflation of the Seventies: What Really Happened?, Advances in Macroeconomics 3, Article 3.

[26] Orphanides, Athanasios. 2001. "Monetary Policy Rules Based on Real-Time Data." *American Economic Review*, Vol. 91, No. 4, 964-985.

[27] Orphanides, Athanasios. 2002. "Monetary Policy Rules and the Great Inflation." *American Economic Review*, Vol. 92, No. 2, 115 - 120.

[28] Orphanides, Athanasios. 2003a. "Historical Monetary Policy Analysis and the Taylor Rule." *Journal of Monetary Economics*, Vol. 50, No. 5, 983-1022.

[29] Orphanides, Athanasios. 2003b. "Monetary policy evaluation with noisy information." *Journal of Monetary Economics*, Vol. 50, No. 3, 605-631.

[30] Orphanides, Athanasios. 2003c. "The quest for prosperity without inflation." *Journal of Monetary Economics*, Vol. 50, p. 633 - 663.

[31] Orphanides, Athanasios. 2004. "Monetary Policy Rules, Macroeconomic Stability, and Inflation: A View from the Trenches." *Journal of Money, Credit, and Banking*, Vol. 36, No. 2, 151 - 175.

[32] Samuelson, Paul A. and Robert M. Solow. 1960. Analytical Aspects of Anti-Inflation Policy, *American Economic Review Papers and Proceedings*, Vol. 50, No. 2, p. 177 - 194.

[33] Stock, James and Mark Watson. 2003. "Has the Business Cycle Changed? Evidence and Explanation." FRB Kansas City symposium, Jackson Hole, Wyoming, August 28-30, 2003.

[34] Taylor, John B. 1992. The Great Inflation, the Great Disinflation, and Policies for Future Price Stability. In A. Blundell-Wignall (ed.), *Inflation, Disinflation and Monetary Policy*. Sydney: Ambassador Press, p. 9 - 31.

[35] Taylor, John B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Series on Public Policy*, Vol. 39, p. 195 - 214.

[36] Taylor, John B. 1998. "Monetary Policy Guidelines for Employment and Inflation Stability." In Benjamin Friedman and Robert Solow (ed.) *Inflation, Unemployment, and Monetary Policy.* Chicago: University of Chicago.

[37] Taylor, John B. 1999. "An Historical Analysis of Monetary Policy Rules." In John B. Taylor (ed.) *Monetary Policy Rules.* Chicago: University of Chicago.

[38] Woodford, Michael. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton: Princeton University Press.

Figure 1: Taylor Curve

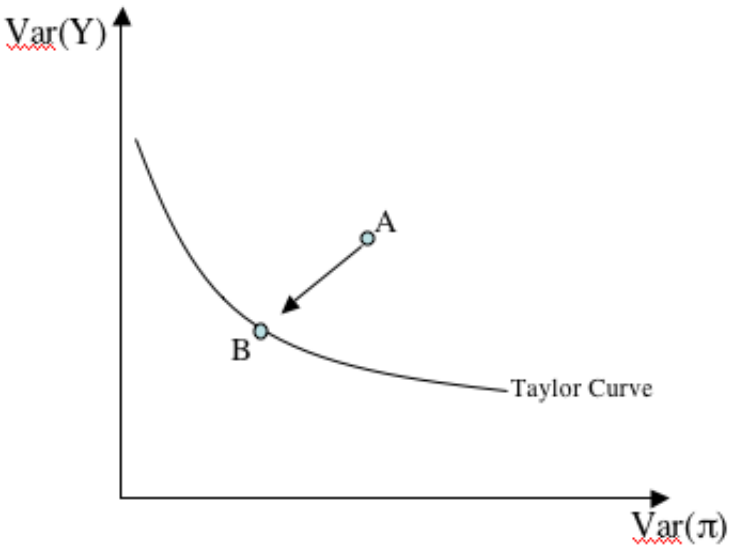

Figure 2: Cost-Push Shocks Under 1970s Fed Doctrine

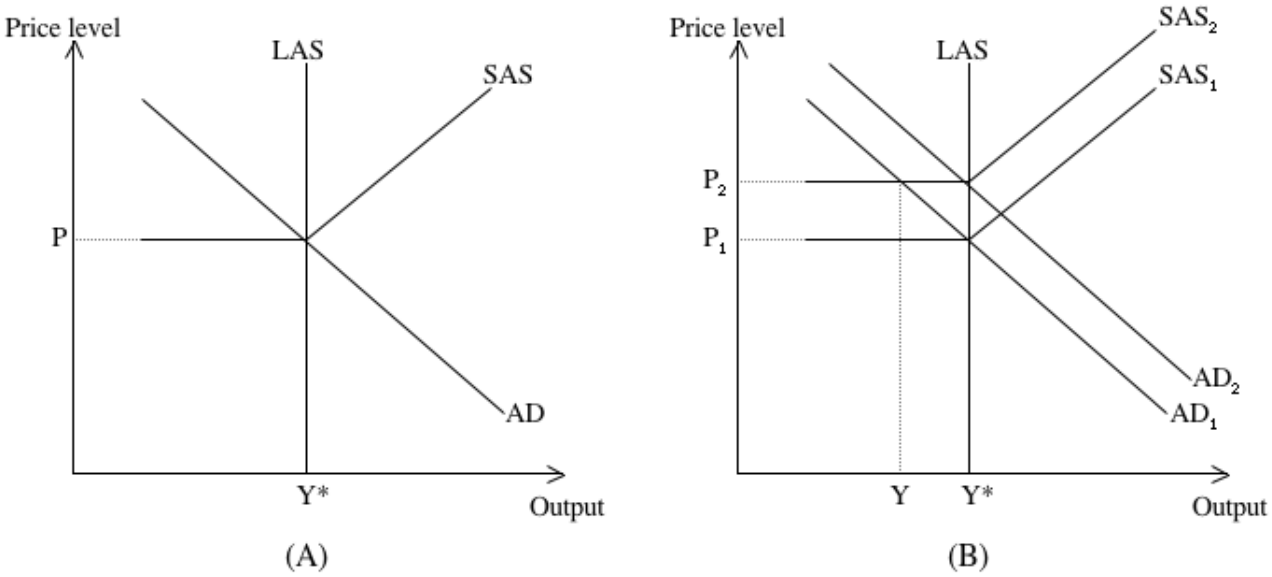

Figure 3: Nominal Income Growth