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L.J. Cristiano and C.J. Gust

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Corresponding author: L.J. Christiano

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Abstract

We use the limited participation model of money as a laboratory for studying the operating characteristics of Taylor rules for setting the rate of interest. Rules are evaluated according to their ability to protect the economy from bad outcomes such as the burst of inflation observed in the 1970s. Based on our analysis, we argue for a rule which: (i) raises the nominal interest rate more than one-for-one with a rise in inflation; and (ii) does not change the interest rate in response to a change in output relative to trend.

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* Department of Economics, Northwestern University

** Federal Reserve Board

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1 INTRODUCTION AND OVERVIEW

Much research in monetary economics is stimulated by the burst of inflation experienced by a number of countries in the 1970s. This research addresses two questions: ‘why did this costly failure of monetary policy occur?’, and ‘what can be done to prevent it from happening again?’

This introduction begins by briefly reviewing the evolution of thinking on these questions, from the focus on institutional reform in the 1980s, to the focus on the design of monetary policy rules more recently. We go on to discuss Taylor rules specifically, and why it is of interest to consider their operating characteristics in a limited participation model of money. We then summarize the results obtained when we do this. An implication of one of our results is that further progress on the analysis of monetary policy rules would benefit from addressing some of the issues of credibility considered in the earlier literature on institutional reform.

1.1 **Identifying Good Institutions**

The initial body of research addressing the two questions in the opening paragraph was stimulated by the seminal papers of Kydland and Prescott (1977) and Barro and Gordon (1983). This work suggested that there was an inflation bias inherent in monetary institutions and that some sort of institutional reform was required to prevent a recurrence of 1970s-style inflation. Examples of such institutional reform include legislative changes that focus a central bank’s mission more sharply on inflation and that grant central banks more independence from the rest of the government. Barro and Gordon's analysis led to the prediction that, absent such reform, inflation would move up and down as the incentives to inflate moved up and down. To operationalize the theory, they made the assumption that the central bank's incentive to inflate is measured by the natural rate of unemployment. However, the Barro and Gordon theory lost some of its appeal in the two decades since they wrote their paper, when the incoming evidence appeared to contradict it.[1] In the United States, a major, persistent drop in the rate of inflation occurred starting in 1980, about three years *before* the unemployment rate started to come down. In Europe and other countries, the incentive to inflate stood at a post-war high in the 1980s and 1990s because the unemployment rate was so high, and yet inflation was very low.[2] Both sets of observations are puzzling from the Barro and Gordon perspective, particularly because they were not preceded by significant, formal institutional reform.[3]

1.2 **Identifying Good Policy Rules**

Alternative approaches to the two questions driving this literature were developed. These place less emphasis on issues of commitment and on the notion that there is

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[1] Evidence that *does* support the Kydland and Prescott (1977) – Barro and Gordon (1983) idea concerns the relationship between inflation and central bank independence. See, for example, the survey in Blanchard (1997, p. 55).

[2] See Christiano and Fitzgerald (1999) and Friedman and Kuttner (1996) for an elaboration on these observations.

[3] Various modifications of the Barro and Gordon approach can potentially reconcile the observations on inflation and unemployment with the theory. For example, one can posit that there is variation over time in policymaker preferences (see Ball (1995), Cukierman and Meltzer (1986), or Rogoff (1985)). Alternatively, by adopting a version of their theory in which the equilibrium variables are a function of the history of past government actions, it is possible to have equilibria in which central banks are 'pushed' into supplying more or less inflation in response to movements in variables other than the natural rate of unemployment (see Chari, Christiano, and Eichenbaum (1998).) This can potentially account for the puzzling observations just cited. We consider this below.

an inflation bias in modern monetary institutions. To explain this, the concept of a monetary policy 'rule' is useful. This specifies how the monetary authority varies the instruments at its command as a function of the state of the economy. The recent research focuses on identifying simple monetary policy rules that will reduce the likelihood of a recurrence of a 1970s style inflation outbreak. The underlying vision is that the poor economic outcomes of the 1970s were a consequence of the poor monetary policy rule in place at that time. The notion is that improvements in our understanding of the economy that have occurred since then, arising both from conceptual advances and from increased data, put us in a position to design a better rule now.[4]

In the quest for good monetary policy rules, rules for setting the interest rate have taken a particularly prominent role. Such rules are called 'Taylor rules' after John Taylor, who has played an important role in popularizing this research. The work has attracted so much attention in part because the interest rate is what central bankers view themselves as controlling. As a result, the research on interest rate rules has substantial potential practical relevance. Although this research is still fairly new, a consensus has already begun to emerge. To explain this, consider the following typical Taylor rule

$$r_t = c + \rho r_{t-1} + \alpha \pi_t + \beta y_t, \tag{1}$$

where π_t is the annualized rate of inflation, r_t is the annualized Federal Funds rate and

[4] For a somewhat pessimistic assessment of the outlook for this approach, see Sargent (1999). He constructs a variant of the Kydland-Prescott/Barro-Gordon model in which the policymaker modifies its views about the structure of the economy as new data come in. As these views evolve, the policymaker adjusts its monetary policy rule. In Sargent's example, this process does not converge. It simply leads to an endless repetition of inflation take-off's like that observed in the 1970s, followed by inflation collapses. Sargent's example is important because it articulates clearly a potential pitfall associated with the design of monetary policy rules. Still, the details of his model are rejected in the sense that it is not able to account for duration of the high inflation in the 1970s. The reason is that the policy maker in Sargent's model, when confronted with the simultaneous rise in inflation and unemployment observed in the early 1970s, would have inferred that high inflation is *not* a productive way to reduce unemployment. According to Sargent's model, the policymaker's reaction to this discovery would have been to keep inflation low. See Sargent's chapter 9 for a further discussion.

y_t is the log deviation of output from trend. The emerging consensus is that a Taylor rule characterized by an aggressive response of the interest rate to high inflation and high output is likely to yield good results.[5] For example, Taylor (1999a) urges the implementation of a rule with $\rho = 0$, $\beta = 1$ and $\alpha = 1.5$.

1.3 The Limited Participation Model as a Laboratory

The strategy of the existing literature evaluates monetary policy rules by studying their operating characteristics in quantitative, economic models. For the most part, the models used in this literature are sticky price, rational expectations versions of the IS-LM model.[6] The question naturally arises: are the existing results robust to alternative, plausible models? We investigate this in the context of one such model. In particular, we investigate the performance of Taylor rules in a simple limited participation model recently studied by Christiano, Eichenbaum, and Evans (1998) (CCE).[7] The mechanisms in this model differ from those in the existing literature. In particular, the friction which generates monetary non-neutrality is a credit market friction, not stickiness in price setting. In addition, the channel from expected inflation to output in this model differs from what it is in the sticky price, rational expectations version of the IS-LM model. Since the source of monetary frictions and the channels from expected inflation to output are not yet well understood, we view our analysis as providing a useful robustness check on the existing literature.

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[5] See the papers in Taylor (1999b). See also Clarida, Gali, and Gertler (1997a) and Kerr and King (1996).

[6] When researchers adopt models not in this paradigm, they often get different results. See, for example, Benhabib, Schmitt-Grohe, and Uribe (1998).

[7] For a comparison of the empirical performance of sticky price versus limited participation models, see Christiano, Eichenbaum, and Evans (1997).

In evaluating a particular parameterization of the Taylor rule, we focus primarily on its ability to rule out bad outcomes.[8] In particular, we want to ensure that the monetary policy rule is not itself a source of welfare-reducing instability for the economy.[9] This can happen for at least two reasons: (i) the rule may enable expectations of inflation to become self-fulfilling, a situation that can occur when the steady state equilibrium of the nonstochastic version of the economy is 'indeterminate' and (ii) the rule may cause the economy to react explosively to shocks.

1.4 Our Results

Three results are reported below that we wish to emphasize here. First, aggressiveness in a Taylor rule is a good idea, but only in response to inflation. Aggressiveness in the response to deviations in output from trend is a bad idea in our model, and can produce welfare-reducing volatility of the kind cited in (i) and (ii) in the previous paragraph. For example, we find that Taylor's recommended values for α, ρ, β places too much weight on output, and result in explosiveness.[10] Second, when we incorporate the monetary policy rule estimated by Clarida, Gali, and Gertler (1997a) to have been followed by the US Federal Reserve in the 1970s into our model, we find that the model exhibits equilibrium indeterminacy. As a result, our model is able to articulate

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[8] We do not seek to identify policy rule parameter values that optimize utility in our model, and we make no attempt to compare the performance of Taylor rules with the unconstrained optimal monetary policy. In our experience, first-order welfare gains are to be had by avoiding the 'bad outcomes' listed next in the text. Once these outcomes have been avoided, there is relatively less to be gained from moving to the globally optimal specification. This is consistent with findings reported in Rotemberg and Woodford (1999), who display a model in which the welfare function is relatively insensitive to alternative specifications of interest rate rules, as long as only parameter values in the region of equilibrium determinacy are considered.

[9] Other research that adopts this perspective on the design of monetary policy rules includes Carlstrom and Fuerst (1998, 1999) and Benhabib, Schmitt-Grohe, and Uribe (1998).

[10] For another model with this property, see Isard, Laxton, and Eliasson (1999).

the view that the burst of high inflation in the 1970s was due to higher expectations of inflation.[11] According to the model, these expectations were translated into higher actual inflation because the policy rule implemented in the 1970s was insufficiently aggressive with respect to inflation. In this respect, our result is similar to the one reported for the sticky price, rational expectations version of the IS-LM model considered by Clarida, Gali, and Gertler (1997a). Still, our result does differ from theirs in one potentially important respect. In our model, a rise in inflation expectations that is self-fulfilling acts to weaken the economy. In a model like that of Clarida, Gali, and Gertler (1997a), such a rise in inflation expectations drives output *up*. This distinction between these two classes of models may provide a way to discriminate between them, since the 1970s are thought to be a period when output was low relative to trend.

The basic intuition underlying these different implications of our model and versions of the standard IS-LM model is simple. The latter emphasize that higher anticipated inflation leads to a reduction in the real rate of interest, which in turn results in a rise in output and actual inflation by stimulating the investment component of aggregate demand.[12] If the central bank adopts a tight money policy every time output and/or inflation is high, this chain of causation from expected inflation to actual inflation is cut. Thus, a high α and/or a high β eliminates equilibria in these models in which high inflation is self-fulfilling.

Now consider our model. Here, higher anticipated inflation induces households to substitute out of cash deposits in the financial sector and towards the purchase of goods.

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[11] This is a view that is also articulated in Chari, Christiano, and Eichenbaum (1998) and Clarida, Gali, and Gertler (1997a).

[12] The basic logic can be illustrated using a textbook Aggregate Supply-Aggregate Demand diagram, with price on the vertical axis and output on the horizontal. In the usual way, a fall in expected inflation shifts Aggregate Demand to the right. Prices rise as the economy moves up along the Aggregate Supply curve. The resulting rise in price corresponds to an actual rise in inflation. This chain linking expected inflation to actual inflation is broken if the authorities shift the Aggregate Demand Curve to the left whenever they see output or inflation rising. High values of α and β do just that.

The resulting shortfall of cash in the financial sector puts upward pressure on the nominal rate of interest. If α in the central bank's policy rule is small, it has to inject liquidity into financial markets in order to prevent a large rise in the rate of interest. This expansion of liquidity would produce the increase in inflation that people anticipated. This is the intuition underlying our finding that a small value of α increases the likelihood that expectations of inflation can be self-fulfilling. Similarly, a large value of α reduces the likelihood that this type of equilibrium could exist.

The previous intuition also shows why a large value of β can actually *increase* the likelihood that inflation expectations are self-fulfilling in our model. That is because the rise in the interest rate that occurs with a rise in inflation under the Fed's policy rule also produces a reduction in output. With a large β, that fall in output operates to offset the Fed's policy of raising the interest rate when $\alpha > 0$. In effect, raising β cancels out the indeterminacy-fighting properties of a high value of α.

Our third and final result that deserves emphasis is the following. Our analysis suggests that the literature on monetary policy rules may have been too quick to abandon the issues of commitment raised by the analysis of Kydland and Prescott (1977) and Barro and Gordon (1983). Our results suggest that a Taylor rule that is sufficiently aggressive to inoculate the economy against a 1970s style inflation outburst may lack credibility because there is a strong – perhaps irresistible – incentive to deviate from it. We computed an example in which a benevolent central bank has an incentive to deviate from such a rule when there is a supply shock which drives prices up and output down simultaneously. In the example, the increased welfare gains from deviating to a *k*% rule at that time are the equivalent of about 0.3% of consumption, forever. To get a sense of the magnitude of this, it corresponds roughly to the amount the federal government spends on the administration of justice, or on general science, space, and technology.[13]

[13] The preliminary estimate for 1997 of consumption of nondurable goods and services in the 1998 Economic Report of the President is $4.8 trillion, so that 0.3% of this is $16 billion. The

This is a substantial amount, and may be difficult to resist for a central bank. A more complete analysis of the concerns raised in this example requires spelling out more clearly the details of the environment. This is beyond the scope of our analysis.[14]

1.5 **Rules and Credibility**

These results on credibility highlight a different possible answer to the two questions posed in the first paragraph. It may be that the problem in the 1970s was not lack of knowledge that a higher value of α might have prevented the inflation take off. Instead, reasoning as in Chari, Christiano, and Eichenbaum (1998), that episode may have reflected a weakness in monetary policy institutions, which simply could not resist accommodating higher inflation expectations in a faltering economy.

That these concerns may be of more than academic interest is suggested by the statements on inflation by Arthur Burns, who was chairman of the Federal Reserve in the 1970s. These suggest that his failure to raise interest rates in line with the dictates of a more aggressive Taylor rule did not reflect ignorance about the connection between money and inflation. He claimed that, instead, it was his fear of the social consequences of such an action that prevented him from implementing a high interest rate policy.[15] Thus, both history and theory suggest that credibility issues should also be

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federal expenditures in fiscal year 1997 on general science, space, and technology was $17 billion, an on the administration of justice it was $20 billion.

[14] Rotemberg and Woodford have pointed out to us in private conversation that a sticky price model may not suffer from the sort of credibility problem emphasized here. In a sticky price model, there is a tendency for output to fall by less than the efficient amount, after a bad technology shock. According to this model, implementing a tight monetary policy at such a time might actually improve the welfare of private agents.

[15] An excerpt from a speech by Arthur Burns in 1977 summarizes views that he repeated often during his tenure as chairman of the Federal Reserve: 'We well know–as do many others–that if the Federal Reserve stopped creating new money, or if this activity were slowed drastically,

considered when designing monetary policy rules.

The next section briefly describes our model. Results are presented in the following section. We close with a brief conclusion.

2 MODEL

In this section, we describe the model used in our analysis and we present some empirical evidence in its favour.

We examine the operating characteristics in our model of the following three variants on (1):

$$r_t = c + \rho r_{t-1} + \alpha E_t \pi_{t+1} + \beta y_t, \text{ (Clarida-Gali-Gertler)}$$

$$r_t = c + \rho r_{t-1} + \alpha \pi_t + \beta y_t, \text{ (Generalized Taylor)}$$

$$r_t = c + \rho r_{t-1} + \alpha \tilde{\pi}_{t-1} + \beta y_{t-1}, \text{ (Lagged Taylor)}$$

As before, r_t is the (annualized) nominal rate of interest that extends from the beginning of quarter t to the end of quarter t. Also, $\pi_t = \log(P_t) - \log(P_{t-1})$, $\tilde{\pi}_t = \log(P_t) - \log(P_{t-4})$, and $y_t = \log(Y_t)$, after a trend has been removed. We refer to

inflation would soon either come to an end or be substantially checked. Unfortunately, knowing that truth is not as helpful as one might suppose. The catch is that nowadays there are tremendous nonmonetary pressures in our economy that are tending to drive costs and prices higher....If the Federal Reserve then sought to create a monetary environment that seriously fell short of accommodating the nonmonetary pressures that have become characteristic of our times, severe stresses could be quickly produced in our economy. The inflation rate would probably fall in the process but so, too, would production, jobs, and profits. The tactics and strategy of the Federal Reserve System–as of any central bank–must be attuned to these realities.' For additional discussion of Burns' (1978) speeches, see Chari, Christiano, and Eichenbaum (1998).

the above as the Clarida, Gali, and Gertler (1997a) (CGG), the Generalized Taylor (GT) and Lagged Taylor (LT) policy rules, respectively.

We study the performance of these three rules in the CEE model. A detailed discussion of the model appears in CEE, and so we describe it only very briefly here. Apart from two modifications, it is basically a standard limited participation model. One modification is that, in addition to having a technology shock, it also has a money demand shock. Traditionally, an important rationale for adopting an interest rate targeting rule was to eliminate the effects of money demand shocks from the real economy (see, for example, Poole (1970)). So, if anything, including them in the analysis should bias the results in favour of the interest rate targeting rule. A second difference is that, although there is still a monetary authority on the sidelines transferring cash into and out of the financial system in our model economy, those transfers are endogenous when the monetary authority conducts its operations with the objective of supporting an interest rate targeting rule.

The representative household begins period t with the economy's stock of money, M_t, and then proceeds to divide it between Q_t dollars allocated to the purchase of goods, and $M_t - Q_t$ dollars allocated to the financial intermediary. It faces the following cash constraint in the goods market:

$$Q_t + W_t L_t \geq P_t \left(C_t + I_t \right),$$

where I_t denotes investment, C_t denotes consumption, L_t denotes hours worked, and W_t and P_t denote the wage rate and price level. The household owns the stock of capital, and it has the standard capital accumulation technology:

$$K_{t+1} = I_t + (1 - 0.02) K_t.$$

The household's assets accumulate according to the following expression:

$$M_{t+1} = Q_t + W_t L_t - P_t \left(C_t + I_t \right) + R_t (M_t - Q_t + X_t) + D_t + r_{kt} K_t,$$

where X_t is a date t monetary injection by the central bank and R_t denotes the gross quarterly rate of return on household deposits with the financial intermediary.[16] Also, D_t denotes household profits, treated as lump sum transfers, and r_{kt} is the rental rate on capital. An implication of this setup is that the household's date t earnings of rent on capital cannot be spent until the following period, while its date t wage earnings can be spent in the same period. As a result, inflation acts like a tax on investment. The household's date t decision about Q_t must be made before the date t realization of the shocks, while all other decisions are made afterward. This assumption is what guarantees that when a surprise monetary injection occurs, the equilibrium rate of interest falls, and output and employment rise. To assure that these effects are persistent, we introduce an adjustment cost in changing Q_t, $H_t = H\left(\frac{Q_t}{Q_{t-1}}\right)$, where H_t is in units of time, and H is an increasing function.[17] The household's problem at time 0 is to choose contingency plans for C_t, I_t, Q_t, M_{t+1}, L_t, K_{t+1}, $t = 0, ..., \infty$ to maximize

$$E_0 \sum_{t=0}^{\infty} \left(1.03^{-.25}\right)^t U\left(C_t, L_t, H_t\right)$$

$$U(C,L,H) = \log\left[C - \psi_0 \frac{(L+H)^{(1+\psi)}}{1+\psi}\right],$$

subject to the information, cash, asset accumulation and other constraints. Here, $\psi = 1/2.5$ and ψ_0 is selected so that $L_t = 1$ in nonstochastic steady state.

Firms must finance J_t of the wage bill by borrowing cash in advance from the financial intermediary, and $1 - J_t$ can be financed out of current receipts. The random variable, J_t, is our money demand shock, and it is assumed to have the following distribution:

$$\log(J_t) = 0.95 \log(J_{t-1}) + \varepsilon_{J,t},$$

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[16] We have $r_t = 4(R_t - 1)$.

[17] To assure that the interest rate effect is persistent, we introduce a cost of adjusting Q_t :

$$H\left(\frac{Q_t}{Q_{t-1}}\right) = d\left\{\exp\left[c\left(\frac{Q_t}{Q_{t-1}} - 1 - x\right)\right] + \exp\left[-c\left(\frac{Q_t}{Q_{t-1}} - 1 - x\right)\right] - 2\right\}$$

where x denotes the average rate of money growth. We set $d = c = 2$ and $x = 0.01$.

where $\varepsilon_{J,t}$ has mean zero and standard deviation 0.01. All of the rental payments on capital can be financed out of current receipts. This leads to the following first order conditions for labour and capital:

$$\frac{W_t\left[R_tJ_t+1-J_t\right]}{P_t}=\frac{f_{L,t}}{\mu},\ \frac{r_{kt}}{P_t}=\frac{f_{K,t}}{\mu},$$

where $\mu = 1.4$ is the markup of price over marginal cost, reflecting the existence of market power. Also, $f_{i,t}$ represents the marginal product of factor i, $i = L,K$, and

$$f(K_t,L_t,v_t)=\exp(v_t)K_t^{0.36}L_t^{0.64},$$

where

$$v_t = 0.95v_{t-1}+\varepsilon_{v,t},$$

and $\varepsilon_{v,t}$ has mean zero and standard deviation 0.01.

Finally, we specify monetary policy in four ways. In the first, money growth is purely exogenous, and has the following second order moving average form:

$$x_t = x+0.08\varepsilon_t+0.26\varepsilon_{t-1}+0.11\varepsilon_{t-2},$$

where ε_t is a mean zero, serially uncorrelated shock to monetary policy and $x = 0.01$. This representation is Christiano, Eichenbaum, and Evans (1998)'s estimate of the dynamic response of M1 growth to a monetary policy shock, after abstracting from the effects of all other shocks on monetary policy. Other representations of monetary policy analyzed here include the CGG, the GT and the LT rules presented above. In these cases, the response of x_t to nonmonetary shocks is endogenous, although we preserve the assumption throughout that $Ex_t = x$.

Figure 1 presents the dynamic response of the model's variables to an ε_t shock in period 2. The percent deviation of the stock of money from its unshocked growth path is displayed in panel c. The magnitude of the shock was chosen so that the money stock is eventually up by 1 percent. Panels a, b and f indicate that the impact effect on output of the monetary policy shock is so great that the price response is nil. Afterward, the price level rises slowly, and does not reach its steady state position until around one year later. The reasons for this sluggish response in the price level are discussed in detail in Christiano, Eichenbaum, and Evans (1997).[18] Next, note the hump-shaped responses of employment, output, consumption and investment. Finally, there is a persistent fall in the interest rate. As emphasized in Christiano, Eichenbaum, and Evans (1998), these patterns are all qualitatively consistent with the data. They support the notion that our model represents a useful laboratory for evaluating the operating characteristics of alternative monetary policy rules.

3 RESULTS

This section presents our quantitative results. We first display the regions of the policy parameter space in which indeterminacy, determinacy and explosiveness occur. Loosely, determinacy corresponds to the case where equilibrium is (locally) unique, so that self-fulfilling inflation episodes are not possible. Indeterminacy corresponds to the case where such equilibria are possible. Explosiveness corresponds to the case in which a shock causes the economy to diverge permanently from its initial position.[19] In the subsequent two subsections we report some calculations to illustrate the economic meaning of the indeterminacy and explosiveness findings. In addition, we

[18] The basic idea is as follows. A positive monetary injection has two effects: (i) it stimulates demand by putting more cash in the hands of households and (ii) it stimulates supply by reducing the rate of interest. The effect of (i) alone is to increase the price level. The effect of (ii) is to decrease the price level. If these supply and demand effects triggered by a monetary shock roughly cancel, there is only a small effect on the price level.

[19] Technically, determinacy, indeterminacy and explosiveness correspond to the number of explosive eigenvalues in the model's reduced form, as in the analysis of Blanchard and Kahn (1980).

discuss the credibility difficulties that may exist in implementing an interest rate rule in practice.

3.1 Indeterminacy, Determinacy and Explosiveness

Figures 2, 3 and 4 report regions of α, β where equilibrium is determinate (white), indeterminate (grey) and explosive (black), for $\rho = 0.0,\ 0.5,\ 1.5$. The results are for the CGG, GT and LT rules, respectively.

We begin with a discussion of the results for the CGG rule, displayed in Figure 2. Consider the case, $\rho = 0$, first. We find that when $\beta = 0$, then determinacy requires $\alpha \geq \gamma$, where γ is a number just below unity.[20] This is analogous to findings reported in Kerr and King (1996) for the IS-LM model (see also CGG). In that model, the value of γ where the economy switches between determinacy and indeterminacy is $\gamma = 1$. Our results resemble those of Kerr and King (1996) and CGG in supporting the notion that an aggressive response to expected inflation reduces the likelihood of indeterminacy. In contrast to CGG, however, we find that the likelihood of indeterminacy and explosiveness increase with β. The intuition for the former result was discussed in the introduction.

Now consider the case $\rho = 0.5$. When $\beta = 0$, then determinacy requires $\alpha \geq \gamma$, where γ is a number just below 0.5. This result, and others not reported, are consistent with the notion that the condition for determinacy is similar to what it was in the case of $\rho = 0$, as long as it is placed on $\alpha/(1-\rho)$, and not α. That is, in several quantitative experiments we found that with $\beta = 0$ and for $0 < \rho < 1$, determinacy requires $\alpha/(1-\rho) > \gamma$,

[20] Note from Figure 2a that determinacy also requires that α not be *too* large.

where γ is slightly below unity. Interestingly, $\alpha/(1-\rho)$ corresponds to the long run cumulative impact on the interest rate of a one-time increase in expected inflation.[21] This suggests that what is important, in guaranteeing equilibrium determinacy, is that the cumulative effect over time of an increase in expected inflation be greater than unity. The precise timing of the response of the interest rise to an increase in inflation matters less. Note also that, like in the $\rho = 0$ case, raising β increases the likelihood of indeterminacy or explosiveness.

Finally, consider the case $\rho = 1.5$. As is to be expected from the $\rho = 0.5$ result, the range of α's which generate determinacy is larger here. As in the other cases, increasing β raises the likelihood of indeterminacy or explosiveness.

Now consider the results reported in Figure 3 for the GT rule. Taylor (1999a) suggests that a good parameterization for (1) is $\rho = 0$, $\alpha = 1.5$ and $\beta = 1$. Interestingly, Figure 3 indicates that, for our model, this parameterization lies in the explosiveness region. Thus, our model indicates that the economy would perform very poorly with this parameterization of the policy rule. According to the results in Rotemberg and Woodford (1999), when $\rho = 0$, $\alpha > 0$, then increasing β raises the likelihood of equilibrium determinacy. In our model, this is not the case. Either we enter the explosiveness region for large β, or we enter the region of indeterminacy. Interestingly, as ρ increases, the region of determinacy expands.

The results in Figure 4 for the LT policy rule resemble those in Figure 3. The preferred parameterization of Rotemberg and Woodford (1999), $\alpha = 1.27$, $\beta = 0.08$ and $\rho = 1.13$ lies in the determinacy region for our model, if we extrapolate between the $\rho = 0.5$ and $\rho = 1.5$ graphs in Figure 4. A notable feature of the LT policy rule is that with ρ large, the determinacy region is reasonably large and resembles the determinacy region for

[21] Thus, suppose there is a one-time pulse of magnitude unity in $E_t\pi_{t+1}$. The impact effect on r_t is α. The lag one effect is $\alpha\rho$, and the lag i effect is $\alpha\rho^i$, for $i = 1, 2, 3, \ldots$. The sum of these effects, as long as $|\rho| < 1$, is $\alpha/(1-\rho)$.

the GT rule.

To summarize, an aggressive response to inflation (or, expected inflation) increases the likelihood of determinacy. However, a more aggressive response to output has the opposite effect in our model. In addition, our results support the notion that choosing a high value of ρ increases the likelihood of determinacy. Finally, the CGG rule appears to have the smallest region of determinacy.

3.2 Illustrating Indeterminacy

We report some calculations to illustrate what can happen when there is indeterminacy. To this end, we worked with two versions of the CGG rule. The first is useful for establishing a benchmark, and uses a version of the CGG rule for which there is a locally unique equilibrium, $(\rho = 0.66, \beta = 0.16, \alpha = 0.61)$. The second uses a version, $(\rho = 0.66, \beta = 0.16, \alpha = 0.32)$, of the CGG rule for which there is equilibrium indeterminacy. We refer to the first rule as the stable CGG rule and to the second as the unstable CGG rule. We consider the dynamic response of the variables in our model economy to a one standard deviation innovation in J_t in period 2.

Figure 5 displays the results for economy operating under a k% money growth rule (dotted line) and under the stable CGG rule. Note that under the k% rule, the results are what one might expect from a positive shock to money demand: interest rates rise for a while and inflation, output, employment, consumption and investment drop. Now consider the economy's response to the money demand shock under the stable CGG rule. As one might expect, this monetary policy fully insulates the economy from the effects of the money demand shock. Figure 5c indicates that this result is brought about by increasing the money stock. Not surprisingly, the present discounted utility of agents in the economy operating under the stable CGG rule, 74.092, is higher than it is in the economy operating under the k% rule, 74.036. These present discounted values are computed under the assumption that the money demand shock takes on its mean value in the initial period, and the capital stock is at its nonstochastic steady-state level.

Now consider the results in Figure 6, which displays the response of the model variables to a money demand shock in two equilibria associated with the unstable CGG policy rule. In equilibrium #2 (see the dotted line), the economy responds in essentially the same way that it does under the stable CGG rule. Now consider equilibrium #1 (the solid line). The money demand shock triggers an expectation of higher inflation. Seeing the inflation coming, the central bank raises interest rates immediately by only partially accommodating the increased money demand.[22] In the following period households, anticipating higher inflation, shift funds out of the financial sector and towards consumption (Figure 6b shows that Q_t rises, relative to its steady state path, in period 3). The central bank responds by only partially making up for this shortfall of funds available to the financial sector. This leads to a further rise in the interest rate and in the money supply. In this way, the money stock grows, and actual inflation occurs. Employment and output are reduced because of the high rate of interest. Investment falls a lot because the higher anticipated inflation acts as a tax on the return to investment. In addition, the rental rate on capital drops with the fall in employment.

The utility level associated with equilibrium #1 is 73.825 and the utility level in equilibrium #2 is 74.110. The utility numbers convey an interesting message. On the one hand, if the stable CGG rule is implemented, then agents enjoy higher utility than

[22] This is difficult to see in Figure 6c because of scale. Money growth in period 2 is nearly 6 percent, at an annual rate, in equilibrium 2. According to Figure 6g, this is enough to prevent a rise in the interest rate in that equilibrium. Money growth in period 2 of equilibrium #1 is less, namely 5.5 percent, at an annual rate.

under the *k*% rule. On the other hand, if the unstable CGG policy rule is used, then it is possible that utility might be less than what it would be under the *k*% rule. In this sense, if there were any uncertainty over whether a given interest rate rule might produce indeterminacy, it might be viewed as less risky to simply adopt the *k*% rule. In a way, this is a dramatic finding, since the assumption that money demand shocks are the only disturbances impacting on the economy would normally guarantee the desirability of an interest rate rule like (1).

3.3 **Illustrating Explosiveness and Implementation Problems**

We now consider a version of our model driven only by technology shocks. We consider two versions of the LT policy rule. One adopts the preferred parameterization of Rotemberg and Woodford (1999): $\alpha = 1.27$, $\beta = 0.08$, $\rho = 1.13$. The other adopts a version of this parameterization that is very close to the explosive region in which β is assigned a value of unity. Figure 7 reports the response of the economy to a one standard deviation negative shock to technology under two specifications of monetary policy. In one, monetary policy is governed by a *k*% rule (see the dotted line), and in the other it is governed by the LT rule just described (see the solid line).

Consider first the *k*% rule. The technology shock drives up the price level, which remains high for a long period of time. Employment, investment, consumption and output drop. There is essentially no impact on the rate of interest. The present discounted value of utility in this equilibrium is 74.095. Consider by contrast the LT rule. The rise in inflation in the first period leads the central bank to cut back the money supply in the following period (recall, this policy rule looks back one period). This triggers a substantial rise in the interest rate, which in turn leads to an even greater fall in employment, output, consumption and investment than occurs under the k% rule. The present discounted value of utility in this equilibrium is 74.036. It is not surprising that in this case, the k% rule dominates the monetary policy rule in welfare terms, and in terms of the variability of output and inflation.

Now consider the operation of the nearly explosive policy rule, in Figure 8. With this rule, responses are much more persistent than under the previous rule. The response looks very much like a regime switch, with money growth and the interest rate shifting to a higher level for a long period of time. Given all the volatility in this equilibrium, it is not surprising that welfare is lower at 73.549.

These examples illustrate the practical difficulties that can arise in implementing an interest smoothing rule like (1). In a recession, when output and employment are already low, the rule may require tightening even further. The social cost of doing that may be such that the pressures to deviate may be irresistible. Numerical results to support this proposition were summarized in the introduction.[23]

4 CONCLUSION

One interpretation of the high inflation experience of the 1970s is that it was the outcome of the Federal Reserve implementing a policy rule which permitted inflation expectations to be self-fulfilling. An important objective of monetary analysis is to design rules which will not allow bad outcomes like this to happen again. This paper

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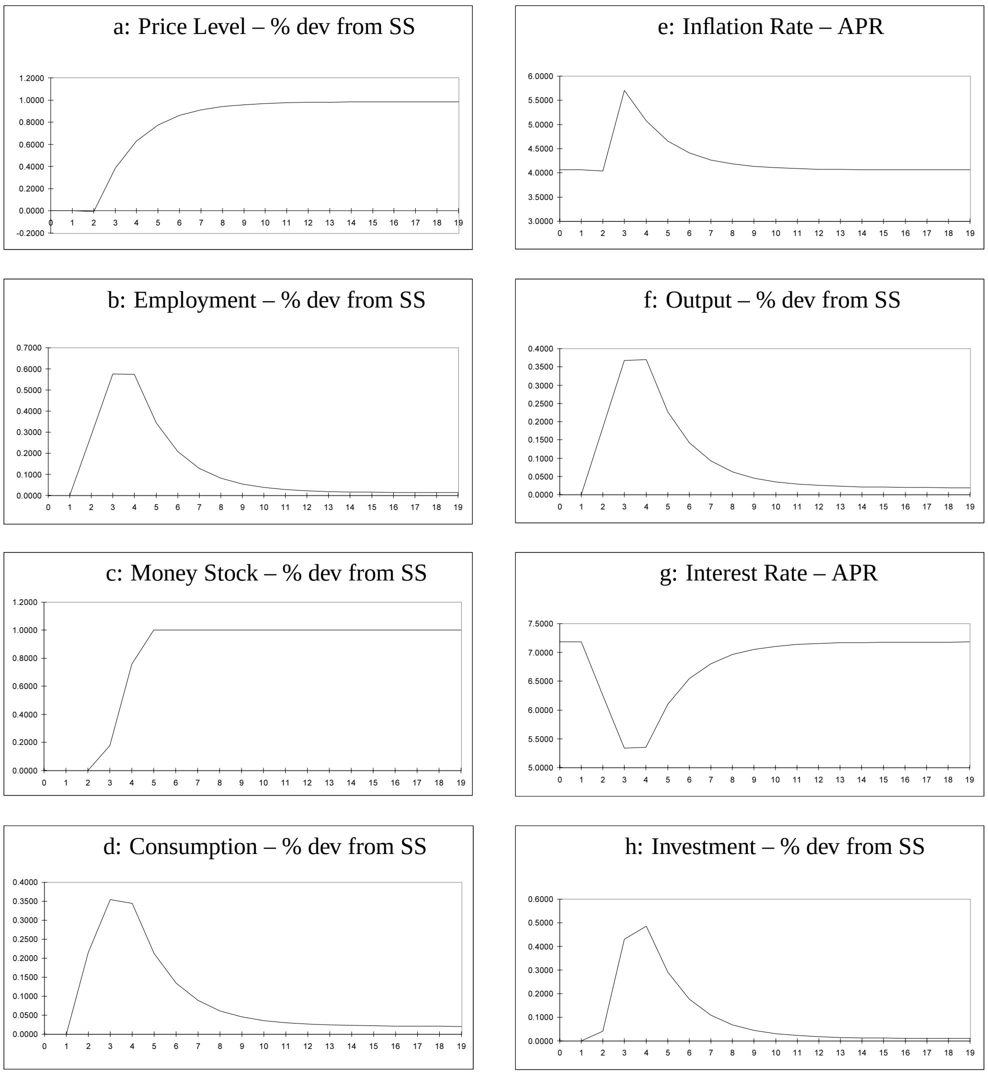
[23] Clarida, Gali, and Gertler (1997b) argue for a specification in which y_t is the deviation from potential output, rather than from trend, as we do here. We suspect that if we replace y_t in the Taylor rule with the deviation from potential, the credibility problem with our policy rule would be worse, for $\beta > 0$. To see why, note that with $\beta(y_t - z_t)$, where z_t is potential output, a fall in potential after a technology shock would act to raise the rate of interest even more.

studied the operating characteristics of Taylor rules in the context of a limited participation model of money. In this model, monetary non-neutrality arises from a particular friction in the household's portfolio decision. Equilibria in which expectations about inflation are self-fulfilling are eliminated when the Taylor rule responds aggressively to inflation and very *little* to output. A strong response to output risks destabilizing the economy. In this respect, the model's implications differ from those of standard sticky price models, which suggest that the possibility of self-fulfilling inflation expectations are ruled out when the Taylor rule responds aggressively both to inflation *and* output.

So, which model should be taken more seriously for purposes of designing monetary policy? We have pointed out that under a sticky price model, equilibria in which inflation expectations are self-fulfilling tend, other things the same, to be associated with *high* output and investment. The limited participation model has the opposite property. This suggests that the latter may have an easier time explaining the 1970s than the former, since this was a period when output and investment were generally low. If a more formal analysis turns out to support this possibility, then the policy implications of the limited participation model would need to be taken seriously.

But, suppose it is not so easy to determine which model, the sticky price model or the limited participation model, is closer to the truth? Robustness considerations suggest picking a rule which works well in either model. And, each model has the implication that bad outcomes are avoided by Taylor rules which respond aggressively to inflation and not to output. So, we conclude that if a Taylor rule is to be adopted, then it should be of this type.

Figure 1 Response of model to exogenous monetary policy shock



% dev from SS: deviation from unshocked nonstochastic steady state growth path expressed in percent terms
APR: annualized percentage rate

Figure 2 Regions of uniqueness, explosiveness and indeterminacy

Clarida-Gali-Gertler rule

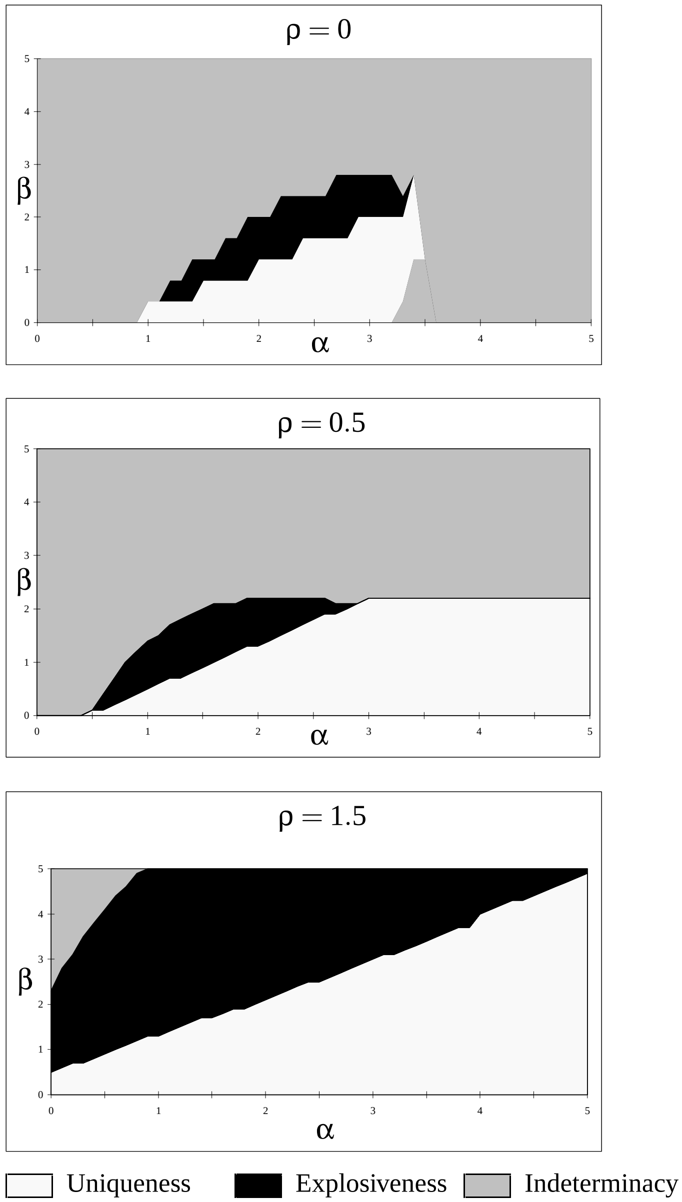


Figure 3 Regions of uniqueness, explosiveness and indeterminacy

Generalized Taylor rule

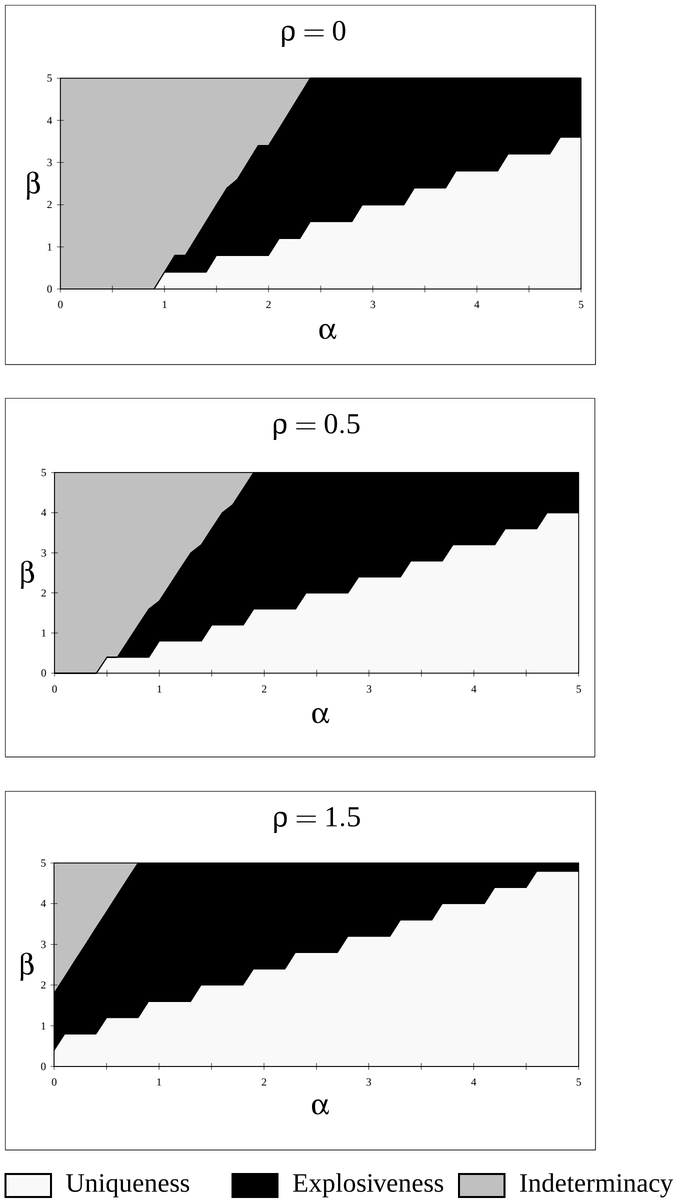


Figure 4 Regions of uniqueness, explosiveness and indeterminacy

Lagged Taylor rule

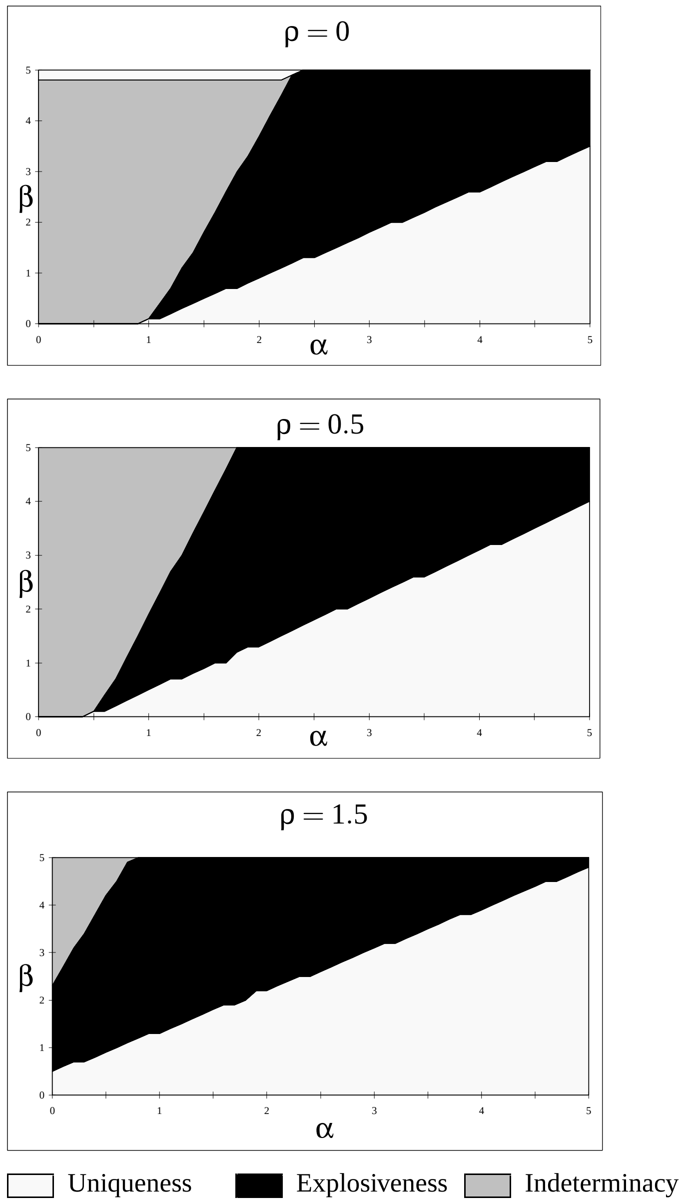
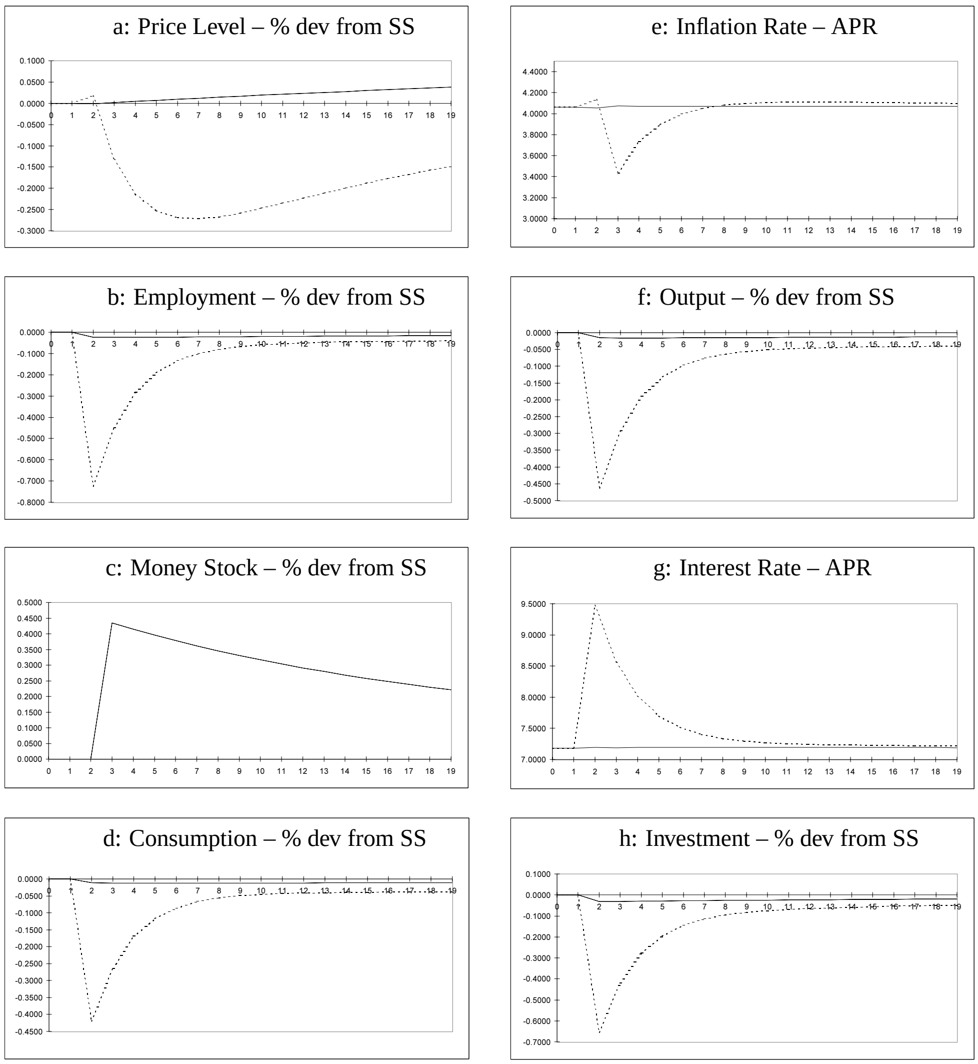


Figure 5 Response to a money demand shock under two policy rules

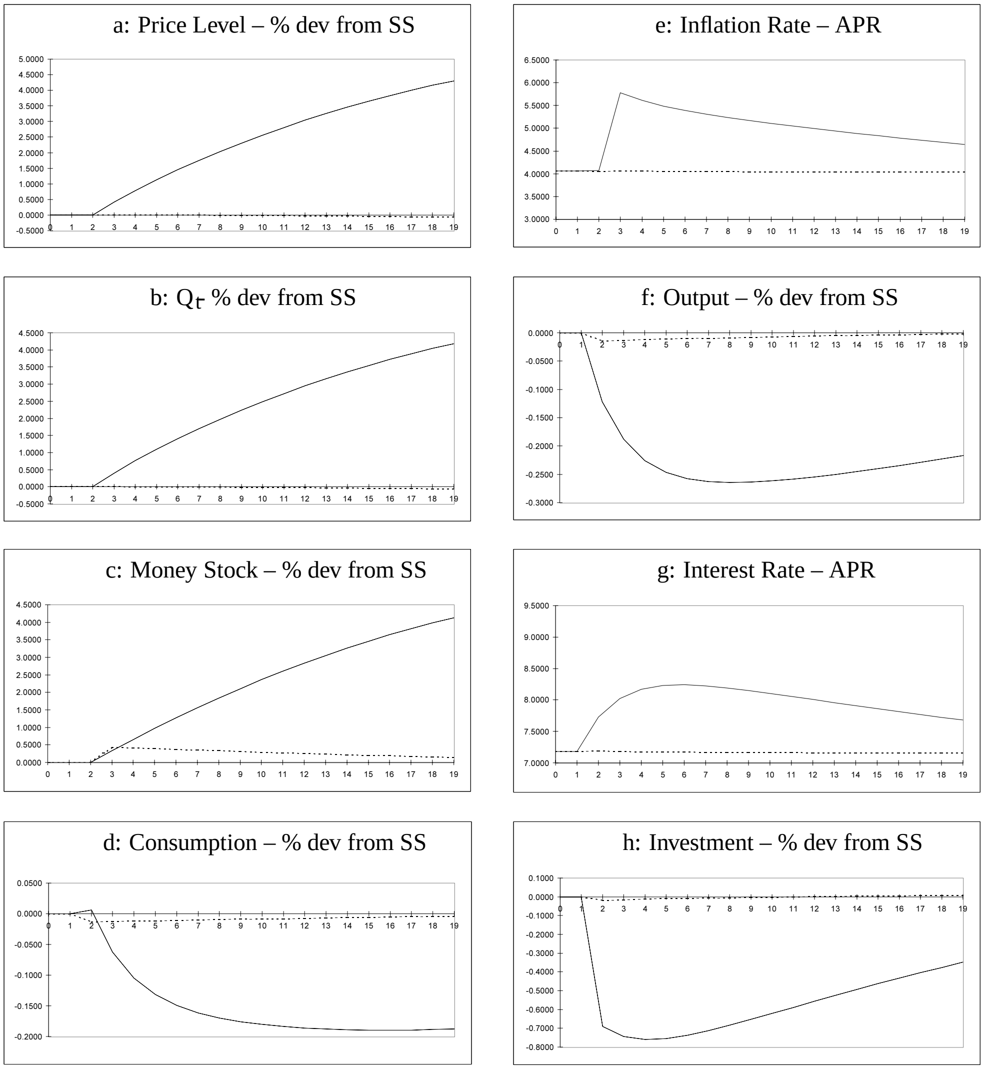


Stable CGG Rule ————

K% Rule - - - - - - - -

See Figure 1 for notes

Figure 6 Response to a money demand shock under unstable CGG rule

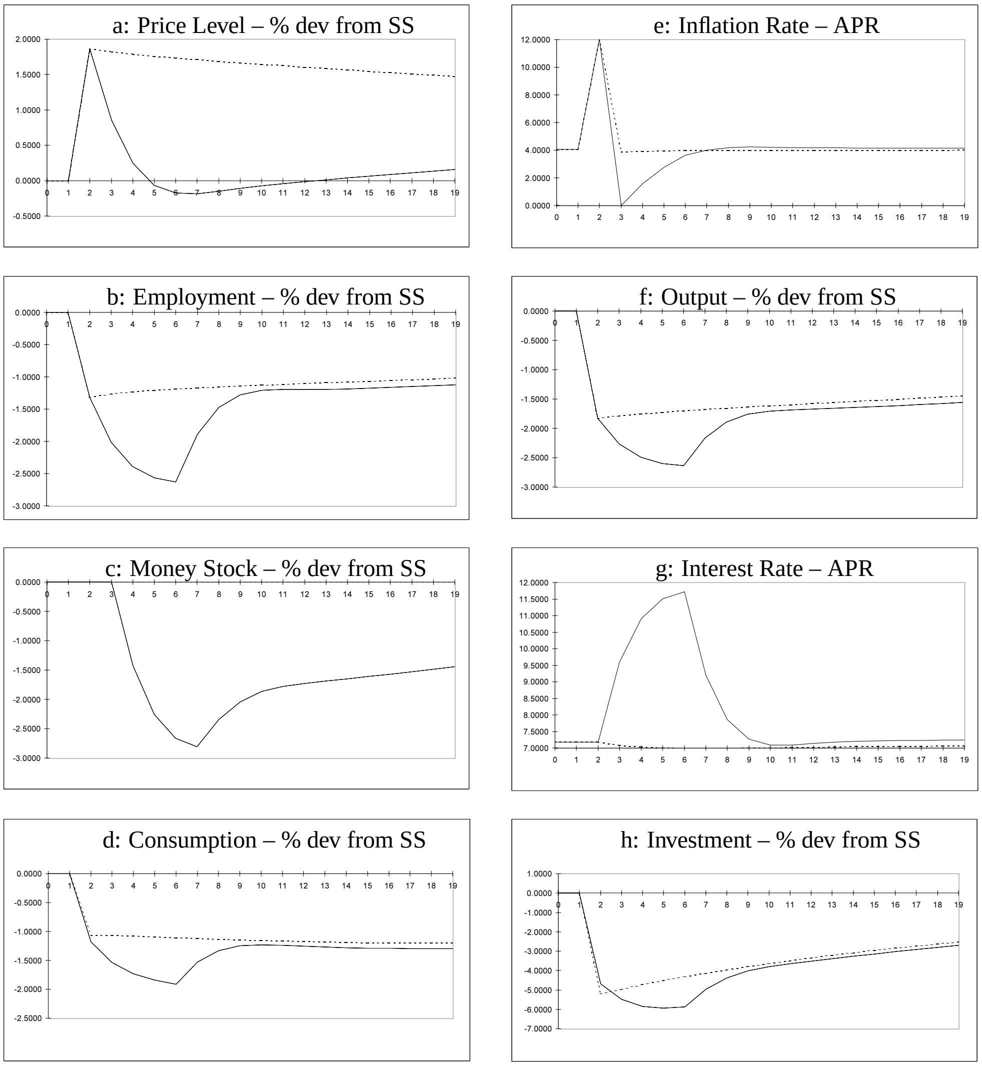


Equilibrium 1 ————

Equilibrium 2 - - - - - - - -

See Figure 1 for notes

Figure 7 Response to a negative technology shock under two policy rules

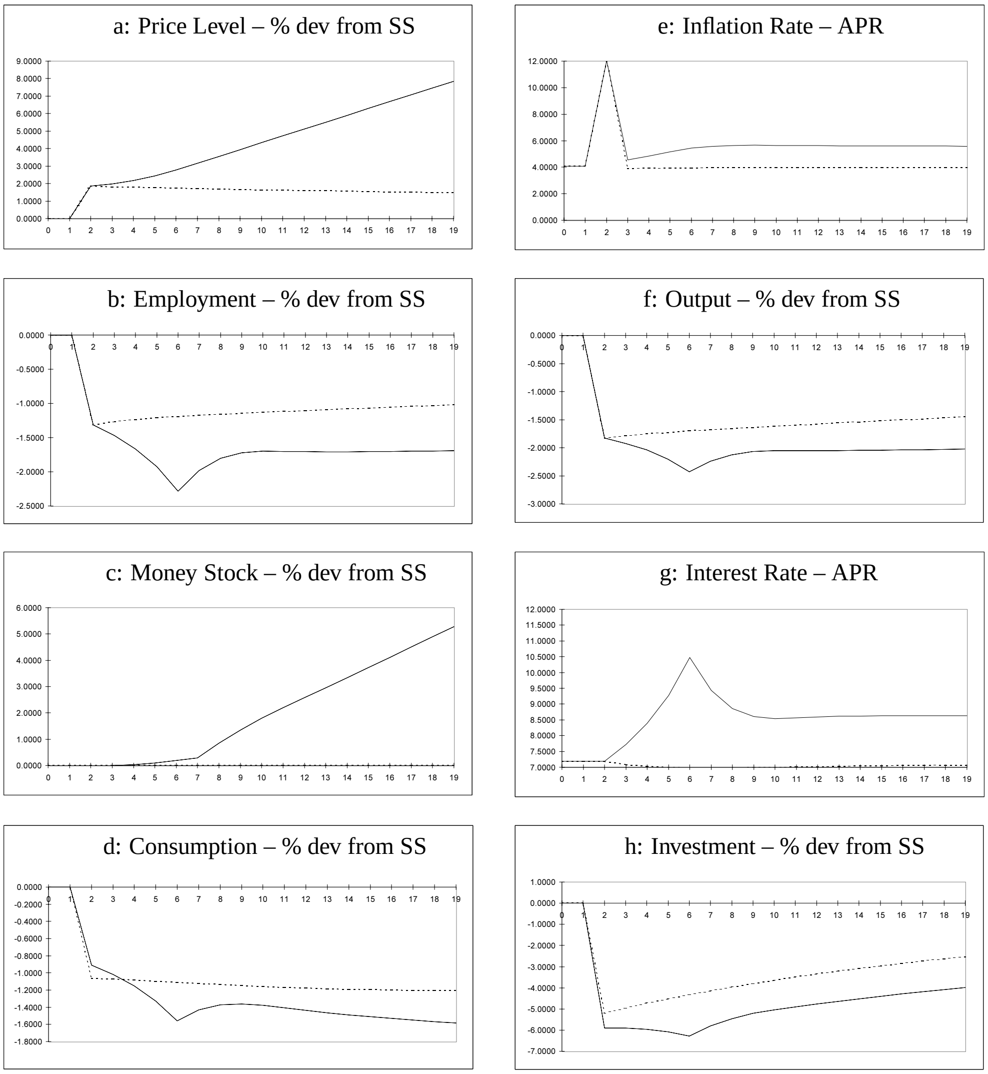


RW Lagged Response Rule ————

K% Rule - - - - - - - -

See Figure 1 for notes

Figure 8 Response to a negative technology shock under two policy rules



Perturbed RW Lagged Response Rule ————

K% Rule - - - - - - - -

See Figure 1 for notes

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COMMENT ON CHRISTIANO AND GUST (1999) AND OTHER RECENT RESEARCH ON THE EFFECTIVENESS AND ROBUSTNESS OF MONETARY POLICY RULES

Peter Isard and Douglas Laxton[1]

The past few years have brought a flurry of papers devoted to studying the properties of simple monetary policy rules in which the short-term nominal interest rate responds directly to measures of both inflation and output gaps. John Taylor of Stanford University has been one of the leading advocates of these types of monetary policy rules, which are now commonly referred to as Taylor rules. Taylor (1998) has suggested that the poor performance of the U.S. economy during the late 1960s and 1970s could have been avoided if policymakers had relied upon the simple Taylor rule as a guideline for policy, provided that the rule was calibrated to respond to inflation and output about as aggressively as the interest rate was adjusted in the late 1980s and 1990s. Along similar lines, Levin, Wieland, and Williams (1998) have recently shown that simple rules linking the change in the interest rate to the variables that enter conventional Taylor rules have desirable properties in four different macro models. However, as Christiano and Gust (1998) argue, one of the shortcomings of most evaluations of monetary policy rules - including the work of Taylor and Levin, Wieland and Williams -is that the effectiveness and robustness of these rules has only been analyzed in a very small class of IS-LM models. Unlike Levin, Wieland, and Williams, Christiano and Gust conclude that these simple interest-rate rules are not robust to model uncertainty. In fact, they argue that it would be very dangerous for policymakers to follow such rules in practice because it would risk a repeat of the great inflation of the 1970s.

The remainder of this note provides our own perspectives on these issues, organized around the following questions.

[1] The views expressed in this paper are those of the authors and do not necessarily represent those of the International Monetary Fund.

1 Is the Taylor rule too simple to be taken seriously?

2 What is the role of monetary policy and what lessons have we learned from historical policy errors? What types of macroeconomic models should be admissible for evaluating the performances of monetary policy rules?

3 Has the robustness issue been explored adequately?

4 Should the optimal policy rules derived from simple linear IS-LM Rational Expectations models be taken seriously by policymakers? What are the specific problems with this class of models?

5 What types of rules, if any, should policymakers rely upon? What are the key elements of good monetary policy?

1 Is the Taylor rule too simple to be taken seriously?

Yes. The reason that the Taylor rule is too simple, and would be dangerous to adhere closely to in practice, reflects the following considerations.

First, as a general point, the effectiveness of any rule for the nominal interest rate depends critically on its success in preventing significant and prolonged deviations of unemployment from the NAIRU, and in thereby preventing an acceleration of inflation. Adjustments in nominal interest rates influence unemployment largely through their effects on aggregate demand, which are transmitted primarily through the real interest rate.

Second, under the Taylor rule, the level of the short-term nominal interest rate depends on the *current* level of inflation, which serves as both an indicator of inflation expectations and a variable that, in conjunction with either the unemployment gap or the output gap, tells the monetary authorities in which direction, and by how much, they should adjust the real interest rate.

Third, inflation expectations have a significant rational and forward-looking component. By contrast, the Taylor rule is myopic and backward-looking insofar as it embodies the current level of inflation as a measure of inflation expectations.

Fourth, monetary policymakers confront considerable uncertainty about the behavior of the economy. Because estimates of the output gap and the equilibrium level of the real interest rate are imprecise, and because economists tend to make serially correlated errors in estimating the output gap, even the best informed policymakers occasionally come to the realization that they had been misgauging the strength of the economy in the recent past, and that their policy errors have led to a state of significant excess demand or significant excess supply [2]. States of significant excess demand or supply can also result from the economy being hit by large and unanticipated shocks [3].

Fifth, when an economy is experiencing a state of significant excess demand, the nominal interest rate adjustments that would be dictated by a backward-looking Taylor rule may be insufficient to raise the level of the real interest rate that is perceived by forward-looking market participants, and might therefore allow excess demand to continue to strengthen, accompanied by a continuing upward spiral in market participants' inflation expectations. As elaborated by Isard, Laxton, and Eliasson (1999) in evaluating the Taylor rule calibrations

[2] For a discussion of the historical errors in estimating potential output and the NAIRU in Canada and the United States, see Laxton and Tetlow (1993) and Orphanides (1998).

[3] As elaborated below, in macro models that are globally linear, states of significant excess demand or supply do not pose risks of large and undesirable consequences (i.e., overheating or deflation). In such linear models, Taylor rules - which are linear functions of the current level of the inflation rate and the output gap (or unemployment gap) - typically embody all the information that is required to forecast inflation and stabilize the business cycle; hence, Taylor rules tend to work very well in linear models. For nonlinear models, by contrast, a rule that depends on current (or past) inflation and output gaps generally must be a nonlinear function of these variables to work well in maintaining macroeconomic stability (see Schaling (1998) and Clark, Laxton, and Rose (1999)), although linear functions of (model-consistent) inflation forecasts and output gaps can work well as policy rules in some nonlinear models (see Isard, Laxton, and Eliasson (1999)).

advocated by Taylor (1993, 1998), in some plausible models it would take only a moderate level of excess demand to break loose the anchor for inflation expectations.

In our view, the Taylor rule is too simple to be taken seriously because it would risk a repeat of the types of monetary policy errors that have been experienced in the past. As Kohn (1999) has emphasized, 'certainly central banks would modify reaction functions if they sensed destabilizing behavior'. Thus, for an economy that was experiencing significant excess demand, a myopic Taylor rule in a world of forward-looking agents would simply not be a credible guideline for monetary policy.

2 What is the role of monetary policy and what lessons have we learned from historical policy errors? What types of macroeconomic models should be admissible for evaluating the performances of monetary policy rules?

In *linear* macro models that embody the long-run natural rate hypothesis, monetary policy does not affect the average level of output, but it does influence the variances of the output gap (i.e., the gap between actual output and potential output) and the inflation rate. Accordingly, the role of monetary policy is often described in terms of a simple chart like Figure 1, popularized by Taylor, which shows the minimum standard deviation of the output gap that is feasible for any standard deviation of the inflation rate [4]. In terms of Figure 1, the role of monetary policy can be characterized as the task of insuring that the economy reaches some point on (or acceptably close to) this policy frontier, where the optimal point on the frontier depends on society's preferences. This role is equivalent to, and is sometimes described more formally as, minimizing a quadratic loss function that is separably additive in the squared output gap and the squared deviation of inflation from target [5].

[4] The policy frontier in Figure 1, which has been taken from Reifschneider, Tetlow, and Williams (1999), was derived for the Federal Reserve Board's FRB/US model of the U.S. economy.

[5] Within the four models considered by Levin, Wieland, and Williams (1998), the optimal calibrations of simple interest rate rules for one model also tend to perform relatively well in the other models in the sense that they generate standard deviations (of inflation and the output gap) that are relatively close to the policy frontiers for the other models.

This view of the role of monetary policy, along with the underlying macro models that support such a characterization, fail to focus on the 'possibility' that monetary policy in reality can have substantial and prolonged effects on the average levels of inflation and output gaps. Most central bankers and economic historians would assert that such effects are a clear reality, not simply a possibility. Linear macro models that do not reflect this possibility risk seducing policymakers into a repeat of the large monetary policy errors of the past and should not be admissible for evaluating the performances of monetary policy rules [6]. Several types of nonlinearities seem relevant in efforts to develop admissible models for monetary policy evaluation. One potentially important element of nonlinearity is the Phillips curve; see, for example, Debelle and Laxton (1997), Laxton, Rose, and Tambakis (1999), and Clark, Laxton, and Rose (1999). A second potentially important element of nonlinearity is the endogenous nature of monetary policy credibility and the apparent asymmetry in the speeds with which the gap between expected inflation and actual inflation responds to the track record of the monetary authorities; see Isard and Laxton (1998) and Isard, Laxton, and Eliasson (1999). Still another important source of nonlinearity, sometimes alluded to as a 'liquidity trap', is the fact that monetary policy cannot push nominal interest rates below a floor of zero; see Laxton and Prasad (1997, 1999) and Sims (1998).

One of the key lessons from history, which reflects both *lags* in the transmission of monetary policy to output and inflation and *nonlinearities* in the output-inflation process, is that it is important for monetary policy to be forward-looking, and to try to take account of all available information that has a significant bearing on the future paths of inflation and output; see Mussa (1985) and Clark, Laxton and Rose (1999). Myopic policy responses to available information can have potentially large costs in terms of output and inflation.

A second key lesson from history is that uncertainty is important. Failing to account

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6 For critiques of policy analysis based on models with linear Phillips curves, see Summers (1988), DeLong and Summers (1998), Isard and Laxton (1996), and Laxton, Rose, and Tambakis (1999). While models that presume global linearity may be useful for forecasting, models designed for policy analysis must allow for the possibility that bad policies can result in bad outcomes.

adequately for uncertainty about the level of potential output, or about the level of the NAIRU, can lead the monetary authorities to adjust interest rates too aggressively in response to estimated output or unemployment gaps, and would risk a repeat of the policy errors of the 1970s, when many central banks provided excessive monetary accommodation in response to inaccurate estimates of the NAIRU and potential output; see Laxton and Tetlow (1993) and Freedman (1996).

A third lesson is that, in evaluating monetary policy strategies, it is important to distinguish between ex ante policy mistakes and ex post policy mistakes. For example, while some may regard the Federal Reserve Board's 'pre-emptive strikes' to raise U.S. interest rates in the Fall and Winter of 1994-95 as, in retrospect, unnecessary or excessive, it would not be appropriate to characterize those policy actions as ex ante mistakes, given the information that the Federal Reserve was acting upon at the time. Ex post, the case for the those actions has been weakened by the combination of downward reductions in estimates of the NAIRU and the greater-than-expected slowdown in U.S. economic activity during the first half of 1995 (partly reflecting spillovers from the economic crisis in Mexico). But ex ante, the case for such pre-emptive strikes can be argued on the basis of a combination of NAIRU uncertainty, asymmetries in the unemployment-inflation process, and significant lags in the monetary transmission mechanism (Isard and Laxton (1998)) [7].

3 Has the robustness issue been explored adequately?

No. As Christiano and Gust (1998) argue, the four models that Levin, Wieland, and Williams (1998) have explored are all quite similar insofar as they all belong to the class of sticky-price IS-LM models. Moreover, as noted above, most evaluations of monetary policy rules

[7] In Congressional testimony explaining the 1994-95 interest-rate hikes, Federal Reserve Chairman Greenspan (1995) appears to have professed belief in a flexible L-shaped (convex) Phillip curve, recognizing that it could be potentially costly to delay an interest rate hike: "In modern economies output levels may not be so rigidly constrained in the short run as they used to be when large segments of output were governed by facilities such as the old hearth steel furnaces that had rated capacities that could not be exceeded for long without breakdown. Rather, the appropriate analogy is a flexible ceiling that can be stretched when pressed, but as the degree of pressure increases, the extent of flexibility diminishes." These arguments apply to guarding not only against overheating but also against serious overcooling where economies are more sensitive to the risks of deflationary shocks; see Laxton, and Prasad (1997).

have relied on linear macro models. We have shown that small extensions to the structures of the models studied by Levin, Wieland, and Williams (1998) to account for nonlinearities in the unemployment-inflation process and uncertainty in the NAIRU can give rise - under either the Taylor rule or the rule advocated by Levin, Wieland, and Williams - to large boom and bust cycles, or to extreme instabilities in inflation expectations; see Isard, Laxton, and Eliasson (1999).

4 Should the optimal policy rules derived from simple linear IS-LM Rational Expectations models be taken seriously by policymakers? What are the specific problems with this class of models?

No. There has been a considerable amount of time devoted to studying the effectiveness and robustness of simple interest rate rules in a class of simple linear IS-LM Rational Expectations models. As noted above, one important lesson from history is that it is important for monetary policy to be forward-looking in order to prevent large boom and bust cycles. The optimal reaction functions derived from these simple linear IS-LM Rational Expectations models are extremely myopic, and we agree with Christiano and Gust that blindly following such rules would risk a repeat of the types of monetary policy errors that have been experienced in the past.

The types of models that have been used by Levin, Wieland and Williams (1998) and several others have two basic problems that make them ill-equipped for studying alternative policy rules. First, the models presume that the monetary policy rule is always perceived to be fully credible by the public, even when the monetary authorities respond myopically to inflation developments or place a very large relative weight on real objectives. Second, in this class of models myopic policy rules only have second-order welfare implications. In our view, any serious model of the economy advanced for studying alternative monetary policy rules must embody the notions that the timing of monetary policy is essential, and that myopic policy responses can, in practice, have significant first-order welfare implications for the economy [8]. We agree with Christiano and Gust that research should be directed away from fine-tuning optimal policy reaction functions in models where there is no real role for monetary policy to focus on a much broader set of models in order to develop strategies for attempting to avoid large policy errors that can result in first-order welfare losses.

In order to contrast the results by Christiano and Gust (1999) with the results by Levin, Wieland, Williams (1998), we report the Blanchard-Kahn (1980) saddle-point stability conditions for two classes of interest rate rules in the context of one of the linear forward-looking models that Levin, Wieland, Williams used to investigate the robustness properties of simple interest rate rules [9]. We show that both classes of rules produce saddle-point stability over an enormous range of parameter values.

Rule 1: Conventional Taylor Rule Generalized for Interest Rate Smoothing

Figure 2 reports the combinations of parameter settings that lead to unique, explosive, and indeterminate solution paths in the Fuhrer-Moore (1995b) model under a conventional Taylor rule that has been generalized to allow for interest rate smoothing.This rule can be written as:

$$rs_t = \rho\, rs_{t-1} + (1-\rho)[w_\pi(\pi_{4t}) + w_y(y_t)] \tag{1}$$

where rs_t is the nominal interest rate setting at time t; π_{4t} is the average inflation rate over the previous 4 quarters; y_t represents the output gap in the Fuhrer-Moore model; and ρ , w_B, w_y are parameters [10]. Note that the interest rate reaction function has been coded so that the

[8] For example, in nonlinear models of the unemployment-inflation process, a failure to prevent large boom and bust cycles will result in a permanently higher level of unemployment; see Mankiw (1988).
[9] The specific model was developed by Fuhrer and Moore (1995a, 1995b). We chose this model because it was more easily accessible than the other models considered by Levin, Wieland, and Williams (1998). We are indebted to Jeffrey Fuhrer for taking the time to help us replicate some of his earlier results. The results reported in this paper have been derived from the parameter estimates reported in Fuhrer and Moore (1995b).
[10] It is convenient here to follow Taylor (1993) in defining the rule in terms of the output gap rather than the unemployment gap. For notational convenience we have dropped the constant term in the equation by assuming that the equilibrium real interest rate and long-run inflation target are zero.

parameters w_B and w_y represent asymptotic long-run responses of the interest rates to the year-over-year inflation rate and the output gap[11].

A striking feature of Figure 2 is that for a very wide range of parameter values - and independently of the speed with which monetary policy reacts to inflation and output gaps (i.e., independently of r) - the model has a stable and unique solution. Indeed, the stability properties of the generalized Taylor rule in this linear rational expectations IS-LM model are extremely simple. The only condition necessary for stability and uniqueness is that the long-run response of the interest rate to year-over-year inflation must be greater than one. Provided this condition is met, even a Taylor rule that reacts much more aggressively to output than to inflation will provide an anchor for inflation expectations in the Fuhrer-Moore model.

What is it that explains the 'excessive stability' generated by Taylor rules in these sticky-price linear rational expectations models? What gives rise to stable macroeconomic behavior even when the monetary authorities respond in a very myopic way to inflation developments, or place an extremely high weight on real objectives relative to inflation objectives? Two assumptions appear to be critical here. The first is the assumption that the economy can be characterized by a Phillips curve that imposes global linearity [12]. The second is the premise - embodied in the simulation exercise - that no matter how myopic policy responses are in the short run, the private sector forms its expectations under the assumption that the monetary policy rule will be adhered to forever.

Isard, Laxton, and Eliasson (1999) study the implications of uncertainty about the NAIRU in a nonlinear Phillips curve model and show that following a Taylor rule blindly not only

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[11]For example, the long-run effects of a permanent unitary change in the output gap is equal to the short-run effect, $(1-\rho)w_y$, divided by $(1-\rho)$.

[12]Under the global linearity assumption, the estimated slope of the Phillips curve (based on post war U.S. data) suggests that unemployment or output gaps have small effects on the inflation process. These small effects imply that it can be very costly, in the context of these models, to reduce inflation once high inflation expectations have become entrenched. It also means that for given inflation expectations, the marginal effect on inflation of an increase in excess demand is small, even when the level of excess demand is high.

would fail to prevent the policy errors of the 1970s but also would almost certainly ensure that they would happen again. For the nonlinear model considered in their paper, even moderately myopic policy rules like the conventional Taylor rule can result in explosive behavior if the economy is subjected to a significant degree of overheating. This reflects a combination of factors. First, even moderate convexity in the Phillips curve implies that at some point the short-run unemployment-inflation tradeoff must worsen considerably when unemployment falls significantly below the NAIRU, and beyond this point a further marginal easing of monetary policy results mainly in inflation with only a very small incremental reduction in unemployment. Second, to the extent that policymakers tend to make serially correlated errors in estimating unemployment and output gaps, the probability of experiencing a significant degree of overheating is heightened [13]. Third, when inflation expectations have a model-consistent component and rational agents possess information about the policy rule and the nonlinear nature of the expansionary effects of monetary policy, attempting to adhere to a conventional Taylor rule with a high weight on imprecise measures of unemployment gaps relative to a backward-looking measure of inflation could be conducive to wide swings or explosiveness in inflation expectations.

As is evident in Figure 2, one of the striking features of the stability conditions for the Fuhrer-Moore model is that they appear to be independent of the degree of interest rate smoothing. This points to a general problem with linear models of the inflation process, which imply that slow monetary policy responses to information about future inflation developments only have second-order welfare consequences. Isard, Laxton, and Eliasson (1999) also show that these stability problems are exacerbated when interest rate smoothing is imposed on an already myopic policy rule.

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[13]One important shortcoming with the analysis provided by Taylor (1998), and Levin, Wieland, and Williams (1998) is that it reflects a strong inherent presumption that policymakers do not make large and persistent errors in estimating output gaps and unemployment gaps.

Rule 2: Levin, Wieland, and Williams (1998) Interest-Rate-Change Rule

Figure 3 reports the regions of stability for the class of interest-rate-change rules suggested by Levin, Wieland, and Williams (1998). In this case, the general form of the reaction function is:

$$rs_t = rs_{t-1} + (w_\pi(\pi_{n,t}) + w_y(y_t)) \quad (2)$$

where $\pi_{n,t}$ is an n-quarter moving average of inflation measured over the previous n quarters. The top and middle panels of Figure 3 consider the two optimal rule parameterizations reported by Levin, Wieland and Williams (1998), where n is equal to 4 quarters and 12 quarters; the longer lag structure on inflation was found to be optimal in a linearized version of the FRB-US model, while the shorter lag structure was found to be optimal in the other linear models that they included in their study. In this case again, even where there is extreme interest rate smoothing and monetary policy responds to very backward-looking measures of inflation, the linear model is stable for an incredibly wide range of weights on inflation and output. The lower panel of Figure 3 considers an even more extreme case of myopic reaction functions, where the reaction function now depends on a six-year moving average of past inflation. Here there is some evidence of instability in the model; but in contrast to the type of results found by Christiano and Gust (1999), in this case explosiveness can arise from setting too low a weight on output.

There are two reasons why the interest rate change rule has extremely poor stabilizing properties in the nonlinear model developed studied by Isard, Laxton, and Eliasson (1999). First, the rule is so myopic and backward-looking that it fails to provide an anchor for inflation expectations. Second, even if one recalibrates the model to reduce the effects of overheating very substantially, an optimal parameterization of the Levin, Wieland and Williams (1998) rule still gives rise to significant boom and bust cycles.

It does not seem to be widely recognized that interest-rate-change rules such as equation 2 are exactly equivalent to targeting a trend change in the price level when $w_y = 0$, and result in approximate price level targeting for small values of w_y. To see this, consider a simple case in which the interest rate change depends solely on the quarterly change in the logarithm of the price level (P) expressed at an annual rate:

$$\mathrm{rs}_t = \mathrm{rs}_{t-1} + \mathrm{w}_\pi \pi_t \qquad (3)$$

where $p_t = 4(P_t - P_{t-1})$. As initial conditions, assume that inflation is on target and the real interest rate is at its equilibrium value (i.e., in period 0, rs_0 = rs* and $p_0 = p^* = p^e$, where * denotes equilibrium).

Now assume that a demand or supply shock raises the inflation rate in period 1 to some arbitrary value p_1. It is interesting, and perhaps even surprising, that monetary policy governed by equation 3 would attempt to move the price level back to the original baseline path. This will be the case, for example, if long-run neutrality holds (as Levin, Wieland, and Williams claim for each of the models they consider), because long-run neutrality implies that the real interest rate must return back to its initial value. But if the real interest rate returns back to control, the nominal interest rate must also eventually return back to control in some period T since, by assumption, the rule is successful in moving inflation back to its initial level of p^*.

If we now sum equation 3 between periods 1 and T we obtain

$$rs_T - rs_0 = w_p \sum_{i=1}^{T} p_i \qquad (4)$$

So $rs_T - rs_0 = 0$ implies

$$\sum_{i=1}^{T} p_i = 0. \qquad (5)$$

Thus, under the assumption that long-run neutrality holds, a policy rule in the form of equation 3 essentially amounts to a price-level targeting rule, since any shock that generates positive inflation must be offset at some point by negative inflation rates. This result obviously carries over to cases in which the contemporaneous inflation rate in equation 3 is replaced by some finite moving average lag structure on past inflation; and even when the rule is extended to include a term in the output gap, as in the general form of interest rate change rules described by equation 2, it continues to bear a close resemblance to price-level targeting. Thus, it should not be surprising that such myopic interest rate change rules can generate extremely poor business cycle properties in models with strong inflation persistence and convexity in the Phillips curve.

5 What types of rules, if any, should policymakers rely upon? What are the key elements of good monetary policy?

Policymakers should not rely mechanically on any monetary policy rule. Fully state-contingent policy rules are not relevant possibilities in a world of incomplete information about the structure of the economy and the nature of shocks, and there is no clearly superior choice between simple (or partially state-contingent) rules and discretion; see Flood and Isard (1989).

We believe that the effectiveness and credibility of monetary policy can be greatly enhanced if policymakers are transparent about their policy objectives, their paradigm (or model) of macroeconomic behavior, their forecasts, and their assessments of the risks. As discussed earlier, it is also critically important for policymakers to be forward-looking, and to adjust their nominal interest rate instrument based on forward-looking assessments of inflation expectations and real interest rates.

Some research has suggested that simple linear inflation-forecast-based rules can come close to optimizing traditional forms of explicit policy objective functions in the context of plausible nonlinear macro models; see Isard and Laxton (1998) and Isard, Laxton, and

Eliasson (1999). Additional research into the effectiveness and robustness of inflation-forecast-based rules may be worthwhile and useful for highlighting risks and avoiding the types of errors that have been made in the past. But with the continuing evolution of the world economy and the periodic occurrence of new types of economic shocks, there will inevitably be times when our best macroeconomic models are recognized to be seriously deficient and when continued adherence to policy rules associated with those models would have strongly adverse welfare consequences. Thus, while simple inflation-forecast-based policy rules may provide useful guidelines for policymakers in attempting to achieve their policy objectives, discretion is also important.

Good monetary policy requires good analysis, including identification of the interest-rate paths (or ‘targeting rules’) that seem consistent or approximately consistent with optimizing the policy objective function. Good monetary policy also requires discretion. And for purposes of both advancing the quality of policy analysis over time and holding policymakers accountable, good monetary policy requires transparency.

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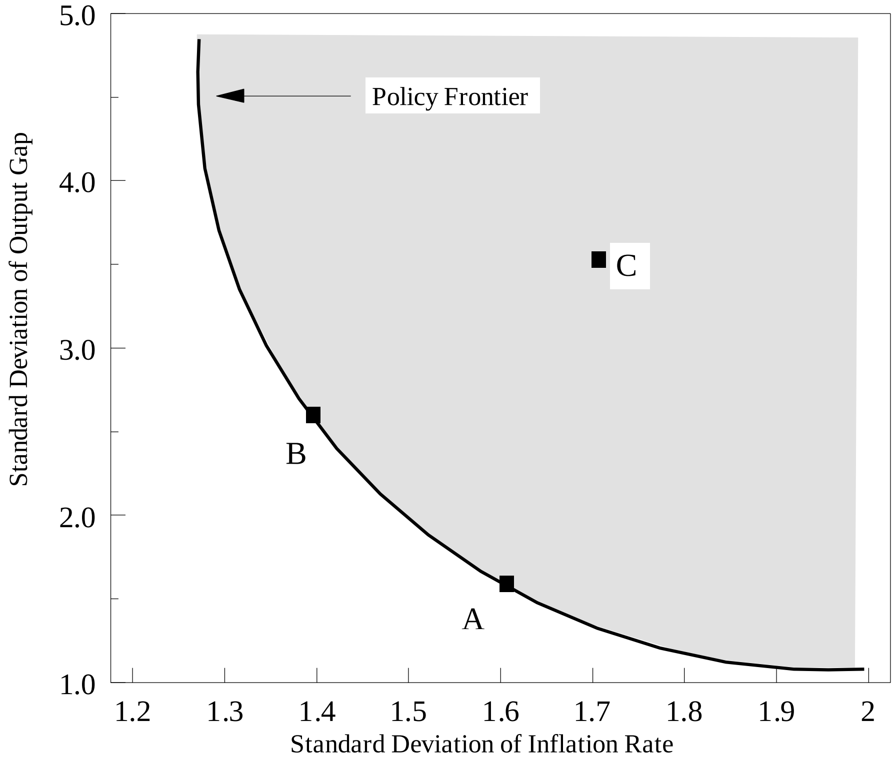
Figure 1: Policy Frontier Derived From the Federal Reserve Board of Governors' Econometric Model of the U.S. Economy



Source: Reifschneider, David, Robert Tetlow, and John Williams, 1999, "Aggregate Disturbances, Monetary Policy, and the Macroeconomy: The FRB/US Perspective," Federal Reserve Bulletin, January, pp. 1-19.

Figure 2: Regions of Uniqueness, Explosiveness and Indeterminacy

(Generalized Taylor Rule in Fuhrer and Moore (1995) Model)

Policy Reaction Function: $rs_t = \mathbf{r} rs_{t-1} + (1-\mathbf{r})[w_p (p\,4_t) + w_y(y_t)]$

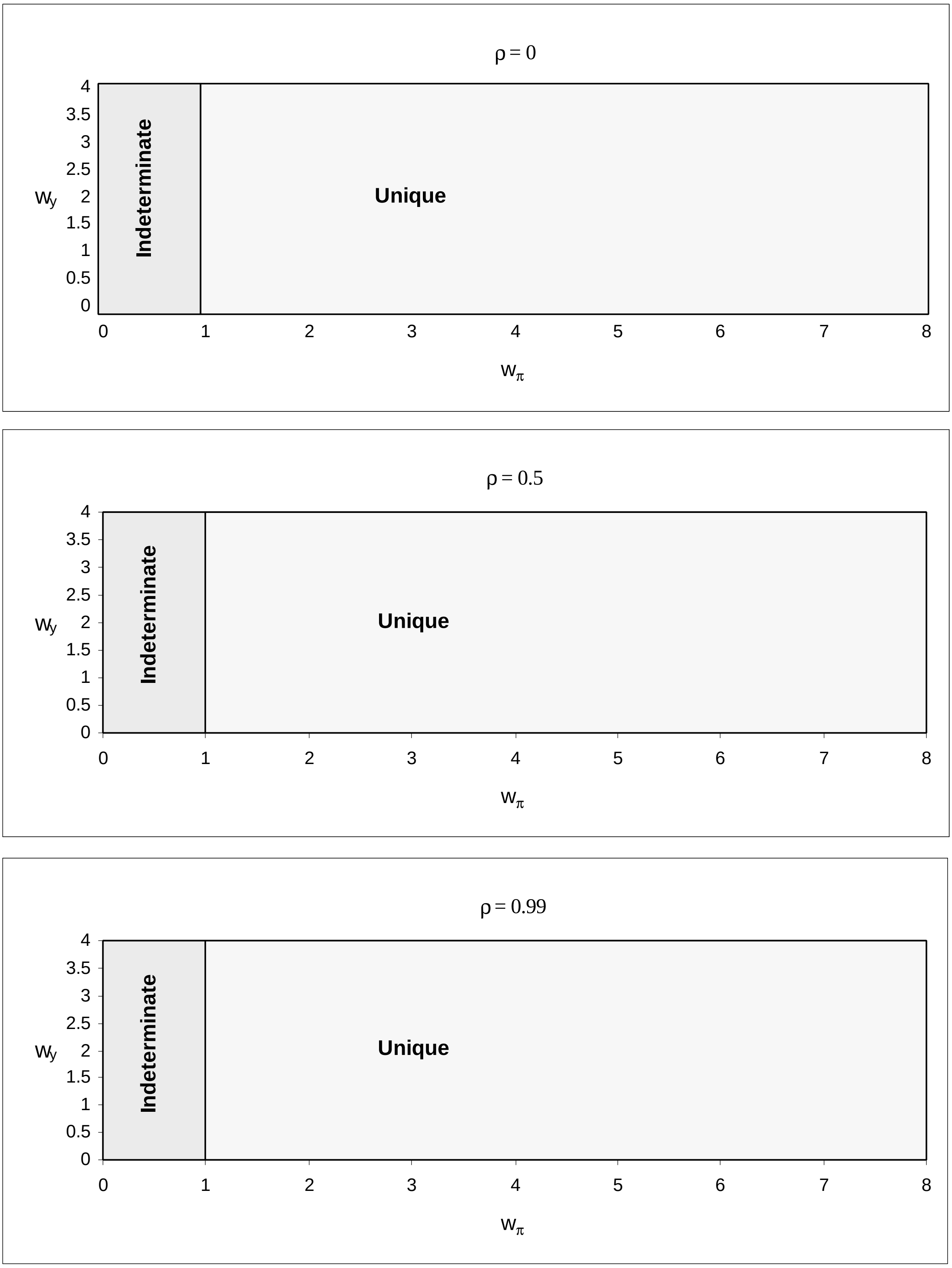


Figure 3: Regions of Uniqueness, Explosiveness and Indeterminacy

(LWW Rule in the Fuhrer and Moore Model)

Policy Reaction Function: $rs_t = rs_{t-1} + w_p (p4_t) + w_y(y_t)$