WORKING PAPER

2004

Department of Economics
Tufts University
Medford, MA 02155
(617) 627 – 3560
http://ase.tufts.edu/econ

Expectations and the Central Banker: Making Decisions the Market Expects to See?*

Edward Kutsoati† Sharun Mukand

Department of Economics
Tufts University
Medford, MA 02155

This version: June 28, 2004

Abstract

This paper develops a simple model to examine conditions under which a monetary policy-making authority is tempted to "follow the market." In doing so, we explore the implications of increased market-consensus on the practice of monetary policy and show that inefficiency in policymaking is most likely precisely when there is a very high consensus that economic fundamentals are weak or strong. In addition, our results also shed light on (i) why interest rates may not be high enough even when the central bank's information suggests a rise in asset prices may be due to 'bubble' shock; (ii) why a central banker may be reluctant to adopt a loose monetary policy even when investors seem to be very pessimistic about the path of future output; and (iii) why, contrary to conventional models, we sometimes observe an upward revision of private sector's forecasts of inflation when the central bank tightens its monetary policy. The results have implications for transparency of monetary policy.

Keywords: Asymmetric information; monetary policy; transparency

JEL Classifications: D82, E44, E52, E58

*This paper originated in discussions with Francisco Gonzalez. We have also benefitted from further discussions with Francesco Caselli and Michael Woodford and comments from Christian Calmes, Yannis Ioannides and several seminar participants. The usual disclaimer applies.

†Corresponding author: edward.kutsoati@tufts.edu. Tel: (617) 627 2688.

1 Introduction

The conduct of monetary policy is often compounded by the central banker's lack of information about the economic environment. It is in such an uncertain environment, that policymakers have typically had to negotiate between the Scylla of low output growth and the Charybdis of inflation. However, the worldwide growth of financial markets and the advent of the information technology revolution has changed matters — reducing the uncertainty, and increasing the consensus among investors, about the future path of the economy. Indeed, it has been suggested that this reduction in uncertainty together with the growth of financial markets has the ability to influence the direction of monetary policy. This is argued most succinctly by Blinder (1998, p.60), who observed that:

> "Central bankers are often tempted to 'follow the markets', that is to deliver the interest rate path that the markets have embedded in asset prices. Living in a central bank for a while has taught me how this temptation arises. Central bankers are only human; they want to earn high marks — from whomever is handing out the grades. While the only verdict that matters is the verdict of history, it takes an amazingly strong constitution to wait that long .... Following the markets may be a nice way to avoid unsettling surprises, which is a legitimate end in itself. But I fear it may produce rather poor monetary policy .... Central bankers must inoculate themselves against whimsy and keep an eye on fundamentals."

In this paper, we examine the role of uncertainty and market opinion in influencing monetary policy. In particular, we ask whether the monetary authority is ever tempted to "follow the market" by delivering policies that the market expects to see, rather than what is socially optimal? We develop a simple framework that captures this strategic interaction between a monetary authority and investors. We consider a situation where the monetary authority and investors are uncertain about the economy's underlying state of fundamentals. This could stem from a good productivity shock to the economy that raises its future output, or a bad shock that has the opposite effect. However, the exact nature of the shock becomes known only after policies and investment decisions have been made. Monetary policy is therefore contingent on the central bank's information about economic fundamentals.

This state-contingent nature of policy itself would not result in any inefficiency, was it not for the assumption that the monetary authority has some private information about the underlying economic environment. While this assumption is easy to justify in an emerging market context, the evidence in Romer and Romer (2000) and Ellingsen and Söderström (2001) suggest that such informational asymmetry can exist even in an advanced economy. In particular, the results in Romer and Romer (2000) show that commercial forecasters of inflation modify their forecasts in response to the Federal Reserve's policy, indicating that interest rate policy contains information beyond what is known by commercial forecasters. They also find that the Federal Reserve seem to possess additional information about the path of future output. Romer and Romer attributes this informational asymmetry to the vast amount of resources the Federal Reserve devotes to forecasting economic trends.[1]

The analysis in this paper is quite distinct from earlier papers on monetary policy in the presence of asymmetric information about economic shocks (e.g., Canzoneri (1985) and Garfinkel and Oh (1993)). The main difference between these earlier papers (and, in fact, most of the literature on the time-inconsistency problem of monetary policy) is that in our framework, private sector's actions take place only *after* the monetary policy decision is known. It therefore shifts the time inconsistency problem of the type highlighted in the standard models (e.g., Kydland and Prescott (1977) and Barro and Gordon (1983a,b)), to one that involves credibility of the central bank's information.[2]

The key feature that investment decisions are made after the direction of monetary policy is known, gives rise to a signaling game between the monetary authority and market participants. In our model, the central bank's interest rate policy provides a signal to the market about the state of the economy. Hence, as noted by Woodford (2003 p.15), the success of monetary policy depends on its ability to shape "market *expectations* of the way in which interest rates, inflation and income are likely to evolve" in the future. However, there is a second aspect to an interest rate policy as a signal. In particular, the choice of interest rate also serves as a signal to the market of the monetary authority's *confidence* in a particular course of action.

If investors are sufficiently uncertain about the underlying state of the economy, then monetary policy will be efficient. This is because the central bank recognizes that the signal that

[1]Peek, Rosengren, and Tootell (1999, 2003) also show that confidential supervisory information about the financial health of non-publicly traded banks that guides monetary policy can be another source of the Federal Reserve's informational advantage. However, Faust, Swanson and Wright (2003) did not find any evidence that Federal Reserve policies reveal any superior information about most macroeconomic statistics to the private sector. But, in general, public statements by the Federal Reserve do attract lots of investor attention partly because the Fed is typically perceived to have private information about the economy.

[2]In the Kydland and Prescott-type models, the private sector form their expectations of inflation based on what they expect the central bank to do. And since any commitment on the part of the central bank to keep inflation low is not credible, the private sector expects a high inflation. Recently, both academics and policymakers have become more skeptical about whether the Kydland-Prescott game really captures the credibility problem that the central bank is generally thought to face: e.g., McCallum (1995), Blinder (1998), and Vickers (1999). Using a model that also assumes that the state of the economy becomes known only after economic decisions and policy has been undertaken, Cukierman (2000) derives an inflation-bias result without appealing to inflation surprises. However, in addition to adopting the standard timing of events — whereby agents act (by forming expectations) before the policy is implemented — Cukierman also assumes that the central bank takes "far more political heat when it tightens preemptively to avoid inflation than when it eases preemptively to avoid higher unemployment" (Blinder (1998 p.19)). So the central bank's objective function is assumed to be more sensitive to the cost of recessions. The inflation bias result in his paper disappears without this assumption.

its policy conveys will be the predominant source of information to investors. Hence, it has an incentive to choose the efficient policy; which completely reveals its information to investors. However if investors are either *very* pessimistic or optimistic about the economy, then inefficiencies in policymaking can occur. For example, when investors are very optimistic about the future path of output, a relevant consideration is that by contradicting the market's and his own prior, the policymaker could be signaling that he is no longer confident about the appropriate course of action. It is this fear of the economic consequences of being perceived as uncertain and lacking confidence about the economic environment, that results in the policymaker's choice of an inefficient policy.

In contrast, when investors believe that the underlying fundamentals of the economy are weak, the central banker's dilemma is very different. Here, the choice of a low interest rate to stimulate the economy, may confirm the negative priors that investors have of a weak economy, resulting in a much lower investment and output levels.[3] So the central bank may be tempted to implement a tighter policy as a signal that the economy is stronger. But, as we shall see, this higher interest rate policy causes investors to revise their expectation of inflation upwards — a result that accords very well with the evidence in Cook and Hahn (1989) and Romer and Romer (2000).

Hence, when put together, our model provides a framework that can be used to simultaneously throw light on the following:

(i) why the central bank may not raise interest rates sufficiently high, even though its private information suggests that an increase in asset prices may be due to a 'bubble' shock;

(ii) why the central bank may behave conservatively and reluctant to lower interest rates sufficiently when investors are "pessimistic" about future output; and

(iii) why we sometimes observe an increase in the private sector's forecasts of inflation when the central tightens its monetary policy.

Our emphasis on the importance of uncertainty in generating inefficiency in monetary policy is shared with Caplin and Leahy (1996). Caplin and Leahy focus on aggregate uncertainty, where they delineate the inefficiency associated with an uncertain Federal Reserve's gradual search for the optimal policy. In a dynamic framework they show that gradual policy cuts of the central

[3] Such claims are commonly made in the financial press. For example, Jess Eisinger noted in the *Ahead of the Tape* column of the May 6, 2003 issue of the *Wall Street Journal*, that "The downside of cutting rates is clear: It might panic the market into thinking that Sir Alan [Greenspan] no longer believes in the coming economic bounce he's been predicting."

bank are ineffectual as investors anticipate further rate cuts and hence delay investing. While this result is similar in flavor to (ii) above, we should emphasize that our focus is on private information in the presence of aggregate uncertainty. Thus, we view this result as complementing Caplin and Leahy's.

Athey, Atkeson and Kehoe (2003) also provide a dynamic model with fluctuating state of the economy. In each period, the monetary authority observes the state of the economy, but investors do not. However, Athey, Atkeson and Kehoe were more interested in a different set of issues: namely, how much *discretion* the monetary authority should be allowed to have in the conduct of its policy. They then determine constraints (e.g., inflation targets) that can be imposed on the monetary authority in order to mitigate her desire to use discretionary policy to stimulate the economy through inflation surprises. Our analysis is much simpler and has a different focus: Because we assume that investors act only after they have observed the direction of monetary policy, our analysis is aimed specifically at the way investors' prior beliefs, and a greater market consensus about the economy, influences monetary policy and macroeconomic outcomes.

The rest of the paper is organized as follows. We present the model in section 2 and provide the equilibrium analysis in section 3. In section 4, we discuss the policy implications of our results and how they relate to the standard models that emphasize the time-inconsistency problem of monetary policymaking. We conclude the paper in section 5. Proofs of all results are in an appendix.

2 The Framework

We construct a simple, static model to capture some of the essential aspects of monetary policymaking, as witnessed in the past few decades. We analyze the strategic interaction between the policymaker (the monetary authority) and investors. The aim of our analysis is to focus on the key influence that investors' expectations have on the direction of monetary policy.

2.1 Description of the Model

Consider an economy that could be in one of two states: a good (G) or a bad (B) state, but the exact nature of the state is revealed only after economic decisions have been made. For example, a good underlying state corresponds to an economic environment where the returns to investment (and hence output and aggregate demand) are relatively high. Conversely, a bad state will be characterized by low aggregate economic activity. We capture this by assuming that total output in state S is given by $Y = SK^{\alpha}$, where K is the level of investment, $\alpha \in (0, 1)$ and the productivity level $S = \{G, B\}$, with $G > B > 0$. We assume that the market's prior that the state is good is $P(G) = \omega$.

In order to facilitate the analysis, we transform these relationships into a logarithmic form by letting $y = \ln Y$ and $k = \ln K$, so that we can think of y as the growth in output. We then define $\overline{y}_S$ as the (exogenous) "potential" output level in state S: that is, $\overline{y}_S = \ln S + \alpha \overline{k}_S$, where $\overline{k}_S$ is corresponding full-employment investment level in state S, with $\overline{k}_G > \overline{k}_B$. For simplicity, we restrict the *fundamental* difference between the two states by assuming that $\alpha(\overline{k}_G - \overline{k}_B) = 1$. As we shall see below, this state-dependence of the economic environment and the potential level of output is consistent with economic models with an unknown natural rate of unemployment.[4]

We assume that inflation is determined by the output gap in the following equation[5]:

$$\pi = E[\pi|\Omega] + \beta(y - \overline{y}_S), \tag{1}$$

where y is determined from the production function and $\beta > 0$ (a constant) measures the output gap effect on inflation. Investors' expectation of inflation is given by $E[\pi|\Omega]$, and the set Ω contains any information that is publicly observed or inferred from the interest rate policy. Since our model is static, we assume that aggregate demand equals the output level in equilibrium: i.e., $y_d = y$.

An appealing aspect of this reduced-form formulation is that it captures in a parsimonious way the state-dependence of inflation: inflation will exceed investors' expectations whenever a loose monetary policy leads to an excessive investment and an over-expansion; or whenever the economy is wrongly perceived to be operating below its potential level — i.e., when $\overline{y}_S$ is thought to be high, when it is in fact *low* (as was suggested by Orphanides (2001) to be the case in the 1970s). On the other hand, a positive supply shock implies a higher $\overline{y}_S$, so that for any given policy, there is a reduction in the level of inflation. So, $\overline{y}_S$ can be considered as the non-accelerating inflation rate of output growth in state S. Our framework is therefore a convenient simplification of the effect of monetary policy on macroeconomic variables.

Finally, we follow the literature by assuming that the monetary authority seeks to balance its goal of stabilizing inflation around zero, while promoting high output growth. That is, the central bank sets its interest rate policy to maximize a welfare function given by:

$$V = \lambda y - (\pi - \overline{\pi})^2/2, \tag{2}$$

[4]For example, our framework is consistent with evidence suggesting that, at any time, there exist a large amount of uncertainty concerning the natural rate of unemployment (e.g., Staiger, Stock and Watson (1994) and Gordon (1997)). A sequence of influential papers by Orphanides (2001, 2002) also find that the Federal Reserve systematically misperceived the state of the economy, especially in the 1970s.

[5]See, for example, Walsh (2002) for a similar formulation.

where $\lambda > 0$ captures the central bank's relative concern for output, and $\overline{\pi}$ is the inflation target, which we assume to be zero (see, for example, Barro and Gordon (1983b) and Walsh (2003, chap.8)).[6]

The timing of events is very simple, and depicted in Figure 1. We assume the initial price level is $P_o = 1$. Then the economy is hit by (an uncertain) productivity shock, S. The central bank observes a private signal about the shock and choose an interest rate policy. Investors then form expectations about the state of the economy and choose the level of investment, taking prices as given. In the last stage, the uncertainty about the shock is revealed, and output and inflation are realized.

Initial price, $P_o = 1$; shock occurs	Bank sees private signal, and choose r	Investors form expectations and choose K	Uncertainty is revealed; y and π are known
0	1	2	3

Figure 1: Timing of events

This also makes the model's mechanics very straightforward: the central bank implements a discretionary interest policy which determines the level of aggregate investment. The investment level then determines the output level, which equals aggregate demand in equilibrium. And finally, inflation (and hence, price level) is determined by equation (1).

It is important to clarify how our model differs from the standard framework for analyzing monetary policy games (e.g., Barro and Gordon (1983b)). In the standard models, the central bank is assumed to choose the inflation rate — either directly or through its choice of the growth of money supply — after the private sector has formed its expectation of inflation. Output is then determined by an expectation-augmented Phillips equation of the form: $y = \overline{y} + \theta(\pi - E[\pi]) + \epsilon$, where $\overline{y}$ is potential output, θ is a positive constant and ϵ denotes a supply shock. In the absence of a supply shock, output exceeds its potential only when there are inflation surprises. Our structure is different. First, because expectations are formed *after the policy is observed,* we need a different channel through which policy affects output. This is accomplished by letting the central bank follow an interest rate policy (rather than target money supply), which in turn influences the level of investment and output through the production function. Hence, in addition

[6] The algebra gets a bit more complicated if we assume the central bank minimizes a quadratic loss function. But the results are qualitatively the same.

to its realism, our description of the timing of events is probably more in accordance with how we view the process of monetary policymaking.

In our framework, it would seem that policymaking for the monetary authority is a simple enough task. All that the policymaker has to do is to choose an interest rate that is 'appropriately' matched to the underlying economic environment — be it more or less productive. However, what makes this otherwise straightforward task difficult, is that the state of the world is not perfectly known. Given this uncertainty, the signals conveyed by the central bank's policy about the underlying economic environment will be important.

In making his assessment of the appropriate policy choice, the policymaker has two sources of information about the underlying state. First, the policymaker is aware that the prior probability that the economy is in the good state is $P(G) = \omega$. This assessment of the productivity of the economic environment is shared by all investors and market participants. In addition, we assume that the policymaker has access to some additional private information about the underlying economic environment. In particular, we assume that the central bank receives an informative private signal, s, about state of the economy; $s = g$ or b. If the economy is good (bad), then it is more likely that the signal will be good (bad); i.e., the reliability of the private signal is given by $P(s = g|G) = P(s = b|B) = \phi > 1/2$. Finally, we assume that $\phi > \omega$ so that the policymaker's private signal is *more* informative than the public signal. This assumption implies that the posteriors are unbalanced, in that $P(G|g) > P(G|b)$. It also means that the limit of $P(G|b)$ (or $P(G|g)$) with respect to both the strength (or weakness) of the prior ω, and the strength of the private signal ϕ, approaches $\frac{1}{2}$. That is, $\lim_{\phi\to 1,\omega\to 0} P(G|g) = \frac{1}{2}$ and $\lim_{\phi\to 1,\omega\to 1} P(G|b) = \frac{1}{2}$. [See proof of Lemma 1 in the appendix for more details]. Intuitively, the posterior probability is more balanced when the prior and the signal *strongly* conflict each other. As will soon be evident, it is the monetary policymaking authority's uncertainty when its signal conflicts with the market's prior, that gives rise to an incentive to make inefficient policy choices.[7]

[7] The qualitative feature of our results will remain the same, if instead, we assume that the productivity shock, and the associated signals, are continuous. In that case, equation (1) will be written as $\pi = E[\pi|\Omega] + \beta(y - \overline{y}) + \xi$, where $\overline{y}$ is the potential output level, and ξ is a shock [See, for example, Walsh (2002) and Jensen (2003)]. If we define $\overline{y} = \frac{1}{2}(\overline{y}_G + \overline{y}_B)$ and let $\delta = \overline{y}_G - \overline{y}_B$, then in our framework, $\xi \in [-\frac{\beta\delta}{2}, \frac{\beta\delta}{2}]$. Hence our model can be said to encapsulate the idea of a varying "natural" output growth. This alternative formulation will however make the analysis less tractable without adding any additional insight. As we shall see, a necessary condition for inefficiencies in policymaking to arise in our model is that there is a significant amount of consensus among investors about the state of the economy.

3 Equilibrium Analysis

We are interested in analyzing the (Bayesian) Nash equilibria to the signaling game. In such an equilibrium, the policymaking monetary authority adopts a payoff maximizing behavioral strategy that describes interest rate $r(\omega, s)$, taking into account the amount of investment such a policy choice will elicit, and its effect on inflation. We assume firms operate in a competitive industry (and so take prices as given), and investors have claims to the profits of firms. So investors make their investment decisions with the aim of maximizing profits.

Suppose the economy inherits a price level $P_o = 1$. Then taking price level P as given, investors choose the level of investment K that maximizes expected profits, by solving:

$$\max_K E[\Pi] = \max_K PE[S|\Omega]K^\alpha - (1+r)K,$$

where $E[S|\Omega] = P(G|\Omega)G + P(B|\Omega)B$, the expected productivity level, and r is the (nominal) interest rate. Here, $PE[S|\Omega]K$ is the (nominal) return from investment and $(1+r)K$ is the cost; e.g., if investors borrowed K at the interest rate r.

For any given interest rate and investors' beliefs about the state of the economy, the first order condition yields an aggregate investment level of $K = \left(\frac{\alpha PE[S|\Omega]}{1+r}\right)^{\frac{1}{1-\alpha}}$. By letting $\ln(1+r) \approx r$, we can write (the log of) investment as $k = \frac{1}{1-\alpha}\left[\ln \alpha E[S|\Omega] - (r - \ln P)\right]$. Since we assumed initial price level of $P_o = 1$, we can replace $\ln P$ with $E[\pi|\Omega]$, investors' expectation of inflation. In equilibrium, actual inflation, $\pi = E[\pi|\Omega]$. Hence, k can be written as:

$$k = \frac{1}{1-\alpha}\left[\ln \alpha E[S|\Omega] - (r - E[\pi|\Omega])\right]. \tag{3}$$

As expected, aggregate investment increases with investors' expectations about the state of the economy, but falls in the *ex-ante* real interest rate, $r - E[\pi|\Omega]$. Substituting this into the production function, (the log of) aggregate output in state S can be written as:

$$y = \ln S + \gamma\left[\ln \alpha E[S|\Omega] - (r - E[\pi|\Omega])\right], \tag{4}$$

where $\gamma = \alpha/(1-\alpha)$. In equilibrium, expectations of inflation must be consistent: using equation (1), this gives

$$E[\pi|\Omega] = r - \frac{1}{\gamma}\left(E[\ln S|\Omega] - P(G|\Omega)\overline{y}_G - P(B|\Omega)\overline{y}_B\right) - \ln \alpha E[S|\Omega], \tag{5}$$

The expression for $E[\pi|\Omega]$ shows that interest rate policy has both a direct and indirect affect on expectation of inflation: the direct effect shows up in first term on the RHS of (5), whereas it impacts indirectly on $E[\pi|\Omega]$ through its effect on investors' information, Ω. This is the signaling effect. Plugging this into equation (4), we can then write aggregate output (and hence, demand) in state S as:

$$y = \ln S - E[\ln S|\Omega] + P(G|\Omega)\overline{y}_G + P(B|\Omega)\overline{y}_B \tag{6}$$

We now analyze a benchmark case in which signals are publicly observable. By pinning down first-best levels of investment as well as optimal policy choices, the analysis of the public signal case facilitates our subsequent analysis of the nature of the policy inefficiency. The analysis in the benchmark case will also show that the policy inefficiencies that we uncover are due to the asymmetry in information, rather then the aggregate uncertainty about the productivity shock.

3.1 Monetary Policy in a First-Best World: Public Signal Case

Consider a situation where the policymaker and investors observe a signal s. Then for brevity, we can write investors' information set as $\Omega = \{s\}$. The monetary authority then chooses r to solve the following problem:

$$\max_r E[V|s] = \max_r \lambda E[y|s] - (1/2)E[\pi^2|s],$$

subject to (1) and (6). Given s and ω, the first order condition yields the interest rate policy:

$$r_s^o(\omega) = \frac{1}{\gamma}\left(E[\ln S|s] - P(G|\Omega)\overline{y}_G - P(B|\Omega)\overline{y}_B\right) + \ln \alpha E[S|\Omega] \tag{7}$$

with $\Omega = \{s\}$. Thus, monetary policy prescribes a rule that matches ω and s to the interest rate policy. The equilibrium policy in the benchmark case also yields a number of features about our economy which are consistent with our understanding of macroeconomic activity. To facilitate comparison in the future, we briefly describe these characteristics:

Investment and output levels: Using equation (3), it can easily be shown that when the signal is publicly available, $k|_{s=g} - k|_{s=b} = \frac{1}{\alpha}\left[P(G|g) - P(G|b)\right] > 0$. That is, the aggregate investment level is higher when the signal is good than when it is bad. This also means that output will be higher when signs point to strong, rather than weak, economic fundamentals. Notice that since a good signal results in a higher level of economic activity, there may well be an incentive for the policymaker to conceal a bad signal when information is private. We explore such incentives in section 3.2.

Ex-ante inflation level: When the signal is publicly observable, the ex-ante inflation rate is equal to the desired level, zero. And since beliefs are consistent, investors also expect inflation to be zero; i.e., $E[\pi|s] = E[\pi|\Omega] = 0$. So, unlike discretionary policymaking in the conventional monetary policy models (e.g., Barro and Gordon (1983 a,b), Persson and Tabellini (1993), Svensson (1997)), the interest rate policy with symmetric information does *not* result in a positive *inflation-bias*. The reason is that, in the full-information case, the central bank internalizes fully the impact of its policy on investors' expectation of inflation since the interest rate policy is observed by investors before any expectations are formed. In other words, policymaking is equivalent to the pre-commitment solution in these earlier models, which also yields zero expected inflation.

Ex-post inflation level: Conditional on observing the signal s, the level of inflation is higher when the underlying state is revealed to be bad, rather than when it is revealed to be good. Furthermore, regardless of the state of the economy, inflation levels are higher if a good (rather than a bad) signal is observed. To see these above relationships first notice that, the unbalanced posteriors imply that, *ex-post*, inflation differs from its expectation: In a good state, the inflation level will be $\pi_G^s = -\beta P(B|s) < 0$, since the economy will be growing at a rate lower than its "potential"; whereas inflation is $\pi_B^s = \beta P(G|s) > 0$ if a bad state occurs. That is, prices rise if the productivity level is *wrongly* perceived to be high, so that the economy expanded beyond its 'potential.'

We are interested in analyzing the case where the central bank's information (i.e., the signal s) is private. In order to facilitate exposition, we restrict parameters to capture two scenarios which we believe to be of interest. Notice that the difference in the optimal policies across good and bad signals (see equation (7)) is given by:

$$r_g^o(\omega) - r_b^o(\omega) = \frac{1}{\gamma}\left[\gamma \ln\left(\frac{E[S|g]}{E[S|b]}\right) - (P(G|g) - P(G|b))\right],$$

which can be greater than or less than zero, depending on the parameter values. We want to restrict parameter values so that when investors are very optimistic (pessimistic) about economic fundamentals, but the central bank's information suggest otherwise, then the first-best policy requires that monetary policy should be contractionary (expansionary).

To see why we impose this restriction, consider an economy that is experiencing a recent run-up in asset prices. This will typically be accompanied by a high degree of investor optimism. However, the central bank may be uncertain whether the rise in asset prices is driven by strong economic fundamentals (i.e., high productivity or good technological shock) or if this is partly due a to "bubble" shock. In a first-best (public signal) world, if the policymaker believes that the rise in asset prices is based on strong economic fundamentals, then we want our monetary authority to retain the relatively low interest rate. On the other hand, if the monetary authority believes that there may be some "irrational exuberance," then parameters should be such that our first-best optimal policy involves a rise in interest rates in order to 'prick the bubble.'

In contrast, consider a second scenario where private agents are pessimistic about economic fundamentals (i.e., ω is small). In such times, if investor pessimism of a weak economy is confirmed by the policymaker's information, then a low interest rate policy to stimulate the economy should be warranted. We would like to capture this scenario with parameter values that ensure that when ω is small, then $r_b^o(\omega) < r_g^o(\omega)$.

ASSUMPTION 1: We assume that $2e^{\frac{1}{2\gamma}} - 1 < \frac{G}{B} < \frac{e^{\frac{1}{2\gamma}}}{2-e^{\frac{1}{2\gamma}}}$.

Lemma 1 *If Assumption 1 holds and* $\phi \to 1$, *then there exists some* ω^o *such that* $r_g^o(\omega) > r_b^o(\omega)$ *if* $\omega < \omega^o$ *and* $r_g^o(\omega) < r_b^o(\omega)$ *when* $\omega > \omega^o$.

Lemma 1 provides parametric restrictions which are sufficient to guarantee that interest rates will be relatively higher (lower) when investors are optimistic (pessimistic) about the economy's path of future output, and a bad signal is publicly observed.[8]

3.2 Monetary Policy in the Private Signal Case

We now suppose that the signal s is private information to the central bank. In this case, investors glean one of three things from the central bank's interest rate policy: (i) whether the signal received by the central bank is good; (ii) whether the signal is bad; or (iii) the monetary policy provides no additional information to them, in which case investors continue to hold their priors, ω. Accordingly, the question we ask is: Given ω, will the central banker ever find it optimal to deviate from the first-best policy, $r_s^o(\omega)$, prescribed by the signal she receives? Equivalently, when (and how) does the central bank reveal its information to investors when the signals are private?

We first look for the conditions under which a separating equilibrium exist with $r \in \{r_b^o, r_g^o\}$, by focusing our attention on the incentives faced by a policymaking monetary authority that observes a bad signal (i.e., type b policymaker). To examine this, consider a deviation from r_b^o to r_g^o by a policymaker who has received a bad private signal, and let $E[V|b, r_s]$ be the expected payoff when the interest rate r_s is chosen after receipt of the private signal b. We define $\Delta \equiv E[V|b, r_g^o] - E[V|b, r_b^o]$, as the net gain from deviation, if investors interpret the deviation as a good signal.

[8]However, as we will see, Assumption 1 (hence, Lemma 1), is only necessary in facilitating our discussion in section 4. It does not affect our qualitative results. What we need to keep in mind is the level of the optimal interest rate policy in the private information case, relative to the first-best (symmetric information) policy, given ω and s.

Then, after a few steps of algebra (as shown in the appendix on page 22), we obtain

$$\Delta(\omega) = \lambda[P(G|g) - P(G|b)] - (\beta^2/2)\,[P(G|g) - P(G|b)]^2 \tag{8}$$

The difference in payoffs has two opposing terms: a positive term resulting from the gain in output, and a negative term due to the inflationary consequences of deviating.[9] By setting the rate r_g, the central bank is able to induce investors to increase the level of investment, resulting in greater output. This gain shows up in the first term on the RHS of equation (8). However because the signal received by the central bank was actually bad, it is more likely that total investment and output would exceed their desired levels (since the economy is likely to have a low full-employment potential output level). This helps to trigger inflation, as shown in the second term in (8). In the proposition that follows, we establish that there exist parameter values for which the monetary authority prefers to deviate from a policy in accordance with its private signal.

Proposition 1 *If the output elasticity of inflation is sufficiently low (i.e., $\beta < 2\sqrt{\lambda}$), then there exists $\underline{\omega}, \overline{\omega}$ (where $\underline{\omega} \leq \frac{1}{2} \leq \overline{\omega}$) such that the monetary authority has an incentive to:*
(i) deviate from the first-best interest rate if investors have sufficiently "optimistic" or "pessimistic" priors about of the strength of underlying fundamentals, i.e. $\Delta > 0$ if either $\omega \geq \overline{\omega}$ or $\omega \leq \underline{\omega}$;
(ii) choose a policy in accordance with the optimal first-best interest rate if investors are sufficiently uncertain about the underlying state i.e. $\Delta < 0$ if $\omega \in (\underline{\omega}, \overline{\omega})$.

Proposition 1 states that the incentive to adopt or deviate from the first-best policy depends on output elasticity of inflation, β, and investors' priors. If β is large, then the inflationary cost of a deviation from the first-best interest rate policy more than offsets the gain in output. Hence, there will be no incentive to deviate. However, when inflation is sufficiently inelastic in output — as most estimates of β will suggest[10] — then the inflationary cost per output gain is so small that the central bank may find it optimal to deviate from r_b^o whenever it observes a bad signal. This occurs if $\beta < 2\sqrt{\lambda}$.

Strikingly, proposition 1 also shows that policy inefficiency is most likely to occur precisely when investors are most confident about the underlying fundamentals, i.e., priors are sufficiently

[9]Note that such incentives do not exist for a central bank that receives a good signal. To see this, define $E[V|g, r_g]$ to be the type-g central bank's payoff from following its signal and setting $r = r_g$, and let let $E[V|g, r_b]$ be her payoff from deviating to r_b. Then the difference in payoffs between deviating and choosing r_g will be given by $E[V|g, r_b] - E[V|g, r_g] = -(P(G|g) - P(G|b))\left[\lambda + (\beta^2/2)\,(P(G|g) - P(G|b))\right] < 0$. Hence, the type-$g$ policymaker never finds it optimal to set a the rate r_b. Doing so hurts the bank both in terms lower output and higher inflation variability.

[10]For example, Rudebusch and Svensson (1999) estimated that the output elasticity of inflation is about 0.14 when inflation is expressed at annual terms. See also Rudebusch (2002). We are grateful to Carl Walsh for alerting us to this.

skewed with ω close to one or zero. This is because, when investors are very optimistic about the path of future output, a relevant consideration is that by contradicting the market's and his own prior, the central bank could be signaling that he is no longer confident about the appropriate course of action. Conversely, if investors are pessimistic about the economy, the bank becomes concerned that by choosing the low, but efficient policy, she will only be confirming the negative priors held by investors. Indeed, it is the fear of the economic consequences of being perceived by investors as uncertain and less than confident about the economy's fundamentals, that gives the central bank an incentive to deviate and choose a policy that does not accord with its private information.

The intuition for this result is best understood by considering the case where $\omega \to 1$, with $\phi > \omega$. Here the priors of the market and the monetary authority are such that both expect a productive economic environment with high returns. Now if the monetary authority receives the private signal b, then its posterior $P(G|b) \to 1/2$. Therefore, adoption of policy r_b^o, will signal to the market that the monetary authority is very uncertain about the underlying state. This uncertainty will result in investors optimally choosing a much lower level of investment, thereby depressing output. In contrast, if the monetary authority deviated and chose r_g^o, then investment is higher not just because of a lower interest rate, but also because the policy is in accordance with the priors of the market. Of course, doing so runs the risk of igniting inflation. But this effect is minimal when the inflationary cost per output gain, β^2/λ, is low. Thus, the monetary authority will have the incentive to choose an inefficient policy when ω is high.

In contrast, consider the case where the market and the central bank are both, ex-ante, uncertain about the underlying state, i.e., $\omega \approx 1/2$. The monetary authority then recognizes that its policy direction becomes the predominant source of information for investors. Hence, upon receipt of the signal b, she is very confident that the underlying state is B and the policy r_b^o is 'appropriate'. If the policymaker deviates from this policy and chooses r_g^o, then more investment will be forthcoming as investors perceive the policy to mean a good state, thus increasing output. However, the positive impact of this deviation on output is more than offset by the serious threat of inflation, as output exceeds the economy's potential given the underlying productivity. Hence, as $\omega \to 1/2$, the central bank adopts the first-best policy rule.

Notice that the central bank's incentive to "follow the market" when ω is high, or "assure the market" when ω is low, introduces a credibility problem quite distinct from that of conventional monetary policy models. In the literature, the central banks' objectives (e.g., Faust and Svensson (2001)), or its incentive to increase output through inflation surprises, has been the focus of its credibility. Such issues are not present here. Rather, the central bank's problem is how to credibly signal its information to investors when that information contrasts with investors expectation about the path of future output. It is not clear that this problem can easily be resolved, even in a dynamic framework. Too see this, suppose ω is low, and $s = g$. Then credibility building requires that the central bank set $r = r_g^o(\omega)$, and use public statements to assure investors that it has received a good signal. But given that the central bank is also uncertain about the state of the economy (recall that, $P(G|g) \rightarrow 1/2$ if ω is low, and $\phi \rightarrow 1$), this strategy may actually hurt its reputation in the future.[11]

Hence, when prior beliefs are sufficiently skewed, the policymaker's behavior is governed by one of two possibilities: either a pooling equilibrium at some interest rate $r^*(\omega)$, or a separating equilibrium in which upon receipt of a good signal, the central bank sets an interest rate higher than $r_g^o(\omega)$. We examine each of these cases in turn.

Pooling Equilibria : Suppose that there is considerable consensus shared by the market and the monetary authority that the underlying state of the economy is either good or bad. If there exists a pooling equilibrium, the policymaker's choice of interest rate provides no information to investors, who continue to maintain their prior beliefs about the economy. To solve for a pooling equilibrium, we determine the optimal choice of interest rate when the signal is good. That is, $\max_r E[V|g,\omega] = \max_r \left(\lambda E[y|g,\omega] - (1/2)E[\pi^2|g,\omega]\right)$, subject to (1), (6) and $E[\pi|\omega]$ is given by (5), with Ω replaced with ω.

The solution to the monetary authority's problem in this case gives the nominal interest rate:

$$r^*(\omega) = \beta(P(G|g) - \omega) + \frac{1}{\gamma}\left[E[\ln S_\omega] + \gamma \ln \alpha E[S_\omega] - \omega\overline{y}_G - (1-\omega)\overline{y}_B)\right] \tag{9}$$

where $E[S_\omega] = \omega G + (1-\omega)B$. Investors expectations of inflation in this case will be $E[\pi|\omega] = \beta(P(G|g) - \omega) > 0$. The output level is then given by $y = \ln S - E[\ln S_\omega] + \omega\overline{y}_G + (1-\omega)\overline{y}_B$. Notice that, since $\lim_{\phi\rightarrow 1,\omega\rightarrow 1} P(G|g) = 1$, expectations of inflation will be close to zero in a pooling equilibrium in which $\omega \rightarrow 1$.

Separating Equilibrium with $r > r_g^o$: Suppose we are in a situation where the priors of the market and of the policymaker are sufficiently skewed, being either very pessimistic (i.e. $\omega < \underline{\omega}$) or very optimistic (i.e. $\omega > \overline{\omega}$). Now consider the monetary policymaker's attempt to signal confidence that the state is good, by trying to separate itself from a less confident policymaker. For such a separating equilibrium to exist, the monetary authority's choice of the interest rate must satisfy two conditions:

[11] This issue is explored more fully by Athey, Atkeson and Kehoe (2003) in a dynamic framework.

(i) first, the interest rate must be high enough ($r > r_g^o$) to ensure that the monetary policymaker who has received the good signal, is able to effectively separate itself from its counterpart who received a bad signal;

(ii) the choice of interest rate should not be 'too high', otherwise, the policymaker with the good signal may just find it optimal to set the pooling rate $r^*(\omega)$ in equation (9).

In order to restate these two conditions that guarantee a separating equilibrium, we first define $E[V|g, r > r_g^o]$ as the bank's expected payoff from choosing an (separating) interest rate $r > r_g^o$, on receipt of private signal g. Similarly, define $E[V|g, r^*]$ as the corresponding payoff in a (possible) pooling equilibrium. The first condition (i), then says that the difference in the central bank's payoff from choosing a higher interest rate, rather than the pooling interest rate $r^*(\omega)$ must be positive: a few steps of algebra (as in the derivation of (8)) yields

$$\Delta_g^* = E[V|g, r > r_g^o] - E[V|g, r^*] = \lambda[P(G|g) - \omega] - (1/2)(r - r_g^o)^2 \geq 0 \tag{10}$$

The term in the square brackets on the RHS of (10) is the gain in output from effectively signaling to investors that the economic fundamentals are, in fact, strong. However, investors revise their expectations of inflation upwards, and this helps to trigger an inflation rate above zero. [More on this in Lemma 2, below]. The loss due to an increase in inflation is shown in the second term. Hence, (10) provides a necessary condition for a monetary authority who receives a good signal to effectively separate itself from one who receives a bad signal.

Similarly, corresponding to condition (ii) above, the monetary authority must not find it optimal to mimic the higher rate $r > r_g^o$ if it receives a bad signal. If we define Δ_b^* as the net gain from mimicking the higher interest rate policy, rather than follow the prescribed policy, despite receiving a bad signal, then accordingly we have:

$$\Delta_b^* = E[V|b, r] - E[V|b, r_b^o] = \lambda[P(G|g) - P(G|b)] - (1/2)[(r - r_g^o) + \beta(P(G|g) - P(G|b))]^2 \leq 0 \tag{11}$$

If these two conditions are satisfied, then on receiving a good signal the monetary policy authority sets an interest rate $r > r_g^o$, which credibly signals to investors that it received a good signal. But since the first-best policy $r_g^o(\omega)$ also conveys the same information, when it is credible, we have the following result:

Lemma 2 *Suppose a separating equilibrium exists for some ω, such that the monetary authority sets $r > r_g^o(\omega)$ if a good signal is observed. Then if investors interpret this higher interest rate policy as a good signal, their expectation of inflation will be given by $E[\pi|r > r_g^o] = r - r_g^o > 0$.*

Lemma 2 states that if the market's priors are sufficiently optimistic or pessimistic then, upon receipt of a good signal, a relatively tighter monetary policy results in an increase in investors' expectations of inflation. To see the underlying intuition, recall that investors observe the choice of interest rate *before* making their investment decisions. This implies that if interest rates are higher than the first-best level, investors infer that the central bank must be very confident about the state of the economy, otherwise it would have opted for a lower, first-best interest rate policy, $r_g^o(\omega)$. This in turn leads to a higher investment. But the resulting higher aggregate investment level will ignite inflation if the economy's fundamentals are indeed weaker. Put differently, a higher than expected rate provides a favorable assessment of productivity, but an unfavorable assessment of inflation (see, for example, Romer and Romer (2000)). Since investors do recognize this, it leads to an upward revision of their expectations of inflation.

Our main result, detailing the cases in which the two conditions for a separating equilibrium hold simultaneously, is stated in the next proposition. It also demonstrate the existence of both pooling and separating equilibria.

Proposition 2 *Suppose* $\beta < 2\sqrt{\lambda}$, *and* $\omega \notin [\underline{\omega}, \overline{\omega}]$. *Then there exists some* ω^*, *such that the monetary authority,*
(i) finds itself in a hybrid separating equilibrium where it chooses an inefficiently high interest rate on receipt of a good signal if $\omega \in (\omega < \underline{\omega})$ *or* $\omega \in (\overline{\omega}, \omega^*)$, *and chooses the first-best interest rate* $r_b^o(\omega)$ *on receipt of a bad signal.*
(ii) finds itself trapped in a pooling equilibrium when prior beliefs are sufficiently high, i.e. if $\omega^* < \omega < 1$, *the central bank chooses* $r = r^*(\omega)$ *regardless of its signal.*

The above proposition depicts the central bank's dilemma. When the market consensus is sufficiently skewed, the monetary authority has no easy way of conveying through its policy choice, the information it has received. This implies that a policymaker faces two options — either to inefficiently raise interest rates or an inefficient pooling interest rate that does not convey its private information to the market.

To see the intuition underlying this inefficiency, consider first Proposition 2(i). This says that through a tighter monetary policy, a central bank is able to resolve the credibility problem when investors are either *pessimistic* or are *moderately* optimistic about the path of future output. Consider first the pessimistic case, where investors believe that economic fundamentals are weak. Here the central bank recognizes that choosing the appropriate interest rate policy r_b^o only confirms investors pessimism, leading to a further dampening of investment and even worse output growth. So, investors rationally expect that the central bank has an incentive to set the interest rate at r_g^o in order to signal that economic fundamentals are actually strong. This results in the central bank choosing an interest rate that is *inefficiently* higher than r_g^o when it actually receives a good signal. As shown in Lemma 2, this causes investors to revise their expectations of inflation upwards. The result is that the *ex-ante* real rate falls to a level that enables firms to invest as much as they would have if the signals were publicly available. Therefore, as with discretionary policymaking in models of monetary policy games, average inflation rates will be positive, with no extra gain in output (relative to the public signal case).

In contrast when investors are moderately optimistic about economic fundamentals (i.e., investors are moderately optimistic with $\omega \in (\overline{\omega}, \omega^*)$), the policymaker faces a similar dilemma. To see this notice that when the market is optimistic then two forces are at work. On the one hand, the policymaker should raise interest rates and dampen investment, in order to 'prick any bubble' that may be forming due to the possible divergence between private sector beliefs and underlying fundamentals. On the other hand, the policymaker has an incentive to *not* confound the market's prior expectations of the underlying state of the economy. This is not only because the unexpected choice of a higher interest rate signals the policymaker's worries about weak fundamentals. It is also because by going against the market's prior, the policymaker also signals his own uncertainty about the right course of action, since the posterior becomes more balanced.

Due to the latter concern, investors rationally expect that the central bank has an incentive to choose the interest rate policy r_g^o, so as to confirm their prior beliefs. The resulting credibility problem forces the central bank to set a relatively higher and *inefficient* rate when it sees a good signal, and the efficient rate r_b^o if a bad signal is observed. But once again resolving such credibility problem here is costly. In particular, investors revise their expectations of inflation upwards, leading to a positive rate of inflation. If investors are very optimistic (such that any further confirmation of their optimism has little impact on aggregate investment), then the gain in output is more than offset by the cost of higher inflation expectations. Hence, the separating equilibrium is only optimal when investors are moderately optimistic (i.e., $\omega \in (\overline{\omega}, \omega^*)$ in proposition 2(i)).

Finally, suppose there is an overwhelming consensus in the market that fundamentals are very strong. For these 'very' high levels of optimism, the central bank sets the interest rate $r^*(\omega)$ regardless of its information, ensuring a pooling equilibrium (proposition 2(ii)). This results in a striking outcome: It says that if optimism about 'strong' fundamentals is overwhelming, then the policymaker will keep rates lower than r_b^o, even if her private information may suggest that such optimism is unwarranted and a 'bubble' may well be in the making. Somewhat ironically, it is precisely the monetary authority's desire to please the market by making decisions that the 'market wants to see', that results in this inefficiency.

4 Monetary Policy, Investment and Inflation: A Discussion

In an uncertain world, we have shown that monetary policy is subject to inefficiencies. Indeed, such inefficiencies are particularly likely when there is considerable consensus amongst market participants about the appropriate course of action. We now sketch the impact on inflation, investment as well as the effectiveness of monetary policy to describe some scenarios of contemporaneous interest. While our analysis is somewhat heuristic, we do believe that it throws light on some of the dilemmas faced by central bankers in many economies.

(i) *Inability of monetary authority to "prick a bubble"*: Though our analysis is essentially static, it does have some interesting implications on the persistence of high asset valuation. Consider a scenario where investors are very optimistic about economic fundamentals, and this manifested itself in the form of higher asset prices as arguably occurred in U.S. economy in the late 1990s. Such investor optimism is analogous to a situation where $\omega > \omega^*$. We have shown in Proposition 2(ii) that, even if the central banker has private information that these optimistic expectations are unwarranted, it may find itself trapped into implementing a policy which conforms to investor expectations — and fail to raise interest rates. It is also easy to show that aggregate investment at the pooling equilibrium will be higher than what it would have been if signals were publicly available: i.e., $k^* - k_b^o = \frac{1}{\alpha}(\omega - P(G|b)) > 0$. This higher investment level further reinforces the inflated asset values. So a "price bubble" could persist for a while, due to an unreasonably high degree of optimism.

This accords well with the Japanese monetary authority's inertia in raising interest rates over the period 1985-89.[12] Furthermore, this also throws light on the slow response of monetary authorities in raising interest rates to dampen the real estate bubble in Thailand and South Korea prior to the crisis in 1997. More controversially, a number of influential economists have also argued that even as (the Federal Reserve chairman) Mr. Alan Greenspan's statement on "irrational exuberance" in December 1996 seemed to indictae the Fed's concern for overinvestment, the Federal Reserve was not sufficiently aggressive in raising interest rates to *gently deflate the emerging bubble* (See, for example, Cechetti (2002) and *The Economist*, Jan. 18th, 2003, p.72). Our analysis provides an explanation of how such "validation of the market" could result.

(ii) *An inefficiently 'aggressive' central banker*: In the *hybrid* separating equilibrium, i.e., $\omega < \underline{\omega}$ or $\omega \in (\overline{\omega}, \omega^*)$, the central bank always adopts the efficient policy r_b^o when it receives a bad signal, but an inefficiently higher interest rate policy when the signal is good. As noted earlier,

[12] Olivier Blanchard (2000) is an excellent (and very prescient) discussion of bubbles and the role of monetary policy.

this inefficiency occurs because for this range of priors, the central bank's information can not be credibly conveyed to investors using the first-best policy. For example, when the market expects a productivity slowdown, investors recognize that the central bank has an incentive *not* to set $r = r_b^o$, since this will confirm the market's pessimism and lead to an even worse economic performance. So upon receipt of a good signal, the central bank "goes out on a limb" by implementing a tighter monetary policy, relative to the first-best, in order to signal to investors that economic fundamentals remain strong. Although this helps to boost investment and output, expectations of inflation increases, and this causes average inflation level to be higher than the desired level of zero.

(iii) *Positive expected inflation level*: It is worth noting that there is a difference between the positive inflation rate result here and the inflation-bias result in the seminal papers by Kydland and Prescott (1977) and Barro and Gordon (1983 a,b), as well as most of the literature that followed in their wake. In these models, the bias in inflation arises because of a central banker's incentive to increase output by springing an 'inflation surprise.'[13] This type of time-inconsistency problem is not present in our model. Instead, investors observe the direction of monetary policy before investment decisions are undertaken, and so the interest rate policy can be used to shape investors' expectations about the state of the economy. This creates a credibility problem about what the central bank really knows; and this problem is intensified when a high degree of consensus about the state of the economy already exist among investors; i.e., when ω is very high or low. Resolving this credibility problem with a relatively tighter monetary policy when $s = g$ is what leads to higher average inflation levels.

This result accords well with the evidence in Romer and Romer (2000). Indeed, Romer and Romer also find that commercial forecasters seem to infer that a rise in the interest rate signals the receipt of unfavorable information about inflation by the Federal Reserve. Accordingly, these forecasters also revise their forecasts of inflation upwards. This result could partly explain the finding in Cook and Hahn (1989) and Kuttner (2001). The evidence in these two papers shows that (unanticipated) increases in the Fed funds rate usually leads to increases in rates on bonds of short to medium-term maturities; possibly, a result of the impact of such contractionary policy on expectations of inflation. Thus, our framework provides a simple, theoretical underpinnings for this empirical finding.

[13] The idea that a central banker has an incentive to "spring inflation surprises" in this class of models has recently been criticized by Blinder (1998) and Howitt (2001). For example, Blinder asserted that "during my brief career as a central banker, I never once witnessed nor experienced this temptation." This sentiment is also echoed by John Vickers, the chief economist at the Bank of England, who noted that "... we have no desire to spring inflation surprises to try to bump output above its natural rate." See Vickers (1999, p.6).

The evidence in Orphanides (2001) suggests that the high inflation rate in the 1970s may be due to a systematic misperception of the state of the economy by the Federal Reserve. This explanation fits well with our model. [See our brief discussion on page 5]. But our results also suggest that there could be another reason for this: Since the 1974–1979 period immediately followed the oil shock, the Federal Reserve and investors may have held opposing views about the state of the economy. Such a scenario will correspond to investors priors given by $\omega < \underline{\omega}$, while the Fed believed that fundamentals were relatively stronger (i.e., $s = g$); exactly where we find that both interest rate and average inflation rate will be high.[14]

Our results can also explain the low inflation rates experienced in most advanced economies in the past decade or so. It is widely believed that there are two reasons behind this success: inflation targeting policy and increased transparency of monetary policy (e.g., Swanson (2004)). First, central banks are increasingly adopting an inflation targeting policy — equivalent to a low λ in our analysis. This lowers $\underline{\omega}$ and increase $\overline{\omega}$, thus increasing the range of ω values for which monetary policy becomes efficient and more transparent. Secondly, if we define past estimate of potential output as $\overline{y} = \frac{1}{2}(\overline{y}_G + \overline{y}_B)$, then the current, stochastic potential output can be captured with $\tilde{y} = \overline{y} + (\omega - \frac{1}{2})(\overline{y}_G - \overline{y}_B)$. This implies that investors do not expect major economic shocks if ω is close to $\frac{1}{2}$; where we find that the interest rate policy will be efficient and information-revealing, and average inflation rates will be low (Proposition 1(ii)). We are therefore inclined to argue that the effect of increased transparency on low inflation rates for most of the 1990s, was aided by the fact that investors did not perceive any major shocks hitting the economy.[15]

(iv) *Transparency and the Public Release of Information:* It may seem that in order to eliminate the bias in inflation (as well as most of the distortions in monetary policy), the central bank can make its information publicly available (e.g, the Green Book forecasts in the U.S.), *before* it decides on the direction of interest rate policy. But, notice an intriguing implication of our analysis. An increase in publicly released information may result in greater consensus about the underlying state of the world. And the consensus generated by this public release of information, may itself result in inefficient policies (recall that Proposition 1 holds for extreme values of ω).

More generally, since investors act *after* they have observed the interest rate policy, the saying that "action speak louder than words" is particularly true when it comes to the credibility

[14] For example, the average rate on the six-month Treasury bill in 1960–73 was 4.6% and the inflation rate averaged 3.3%. However, between 1974–78, while the nominal rate on the six-month Treasury bill rose to an average of 6.5%, the inflation rate over the same period soared to an average of 7.3% (see Wilcox (1983)).

[15] Even in the case of over-investment, as occurred in the U.S. from late 1999 to 2001, our model predicts relatively low rate of inflation. In our model, such a shock occurs when $\omega^* < \omega < 1$, and the expected inflation at the pooling equilibrium here is given by $\beta(P(G|g) - \omega) > 0$. Since $\omega \to P(G|g)$ as $\omega \to 1$, the inflation rate is close to the desired level of zero, even when investors seem to be overly optimistic.

problem identified here. Investors may not accept at face value such public releases before a policy is undertaken. As pointed by Romer and Romer (2000 p.456), they will be concerned that the central bank may have an incentive to misrepresent information that they have received. The reader may conjecture that the policy inefficiencies identified here can be eliminated with reputation-building in a dynamic framework. But as we noted earlier, this may not be easy when ω is low. However, it may be easier to use the first-best policy, and public releases of information, to build such reputation when investors are very optimistic (e.g., $\omega > \omega^*$) and the central bank receives a good signal. This is because, not only is the central bank more confident about the state of the economy (note that, $P(G|g) \to 1$ if ω is high), but also if it is *wrong*, the market would also be wrong, and this is not likely to hurt the central bank's reputation.

5 Conclusion

Perhaps, the most difficult part of monetary policymaking is that, at any time, there is some degree of uncertainty about the state of the economy. This paper develops a parsimonious framework to examine the impact of market expectations about the state of the economy on the practice of monetary policy. We show that the efficient policy is adopted only when investors are sufficiently uncertain about the economy. Strikingly, inefficient choices in monetary policy are most likely precisely when there is sufficient consensus in the economy.

We show that, indeed, a central bank may have an incentive to enact policies that the 'market wants to see', rather than what is socially optimal. Our model also provides a framework that simultaneously throws light on (i) why interest rates may not be high enough even when the central bank's information suggests that an increase in asset prices may be due to a bubble shock; (ii) why the central bank may be reluctant to lower the interest rate when investors seem to be very *pessimistic* (or moderately optimistic) about the path of future output; and (iii) why we sometimes observe an upward revision of private sector's forecasts of inflation whenever the central bank tightens its monetary policy.

Furthermore, it should be emphasized that the inefficiency in monetary policy that we delineate is distinct from the one emphasized in the vast literature on the time-inconsistency of monetary policy. Accordingly, it shows how market expectations can trap policymakers into enacting policies that result in a higher level of inflation — without appealing to the idea of "inflation surprises." Hence, it provides an alternative explanation of what may underlie high inflation rates, especially during the 1970s.

Appendix

Proof of Lemma 1: First, notice that, by Bayes' rule, the posterior beliefs that the state of the economy is good will be given by:

$$P(G|g) = \frac{\omega\phi}{\omega\phi + (1-\omega)(1-\phi)} \quad \text{and} \quad P(G|b) = \frac{\omega(1-\phi)}{\omega(1-\phi) + (1-\omega)\phi} \tag{Ap.1}$$

Clearly, the $\lim_{\phi\to 1,\omega\to 1} P(G|g) = 1$ and $\lim_{\phi\to 1,\omega\to 0} P(G|b) = 0$. Now consider the limit of $P(G|b)$ as both ϕ and ω approaches 1. Since $\phi > \omega$, the $\lim_{\phi\to 1,\omega\to 1} P(G|b)$ will be equivalent to $\lim_{\phi\to 1,\omega\to\phi} P(G|b) = \lim_{\phi\to 1} \frac{\phi(1-\phi)}{\phi(1-\phi)+(1-\phi)\phi} = \frac{1}{2}$. Similarly, since $\omega > 1-\phi$, the $\lim_{\phi\to 1,\omega\to 0} P(G|g)$ will be equivalent to $\lim_{\phi\to 1,\omega\to(1-\phi)} P(G|g) = \frac{1}{2}$. [Recall that $P(B) = 1-\omega$ and $P(b|B) = \phi$; and since the signal is more informative than the prior, we have $\phi > 1-\omega$ or $\omega > 1-\phi$]. Hence, if $\phi \to 1$, then $\lim_{\omega\to 1} \gamma \ln\left(\frac{E[S|g]}{E[S|b]}\right) = \gamma \ln \frac{2G}{G+B}$, and $\lim_{\omega\to 1}(P(G|g) - P(G|b)) = 1/2$. But $\lim_{\omega\to 0} \gamma \ln\left(\frac{E[S|g]}{E[S|b]}\right) = \gamma \ln \frac{G+B}{2B}$, and $\lim_{\omega\to 0}(P(G|g) - P(G|b)) = 1/2$. We know that

$$r_g^o(\omega) - r_b^o(\omega) = \frac{1}{\gamma}\left[\gamma \ln\left(\frac{E[S|g]}{E[S|b]}\right) - (P(G|g) - P(G|b))\right],$$

so if

$$\gamma \ln \frac{2G}{G+B} < 1/2 \quad \text{and} \quad \gamma \ln \frac{G+B}{2B} > 1/2 \tag{Ap.2}$$

then there exists some ω^o such that $r_o^g(\omega) < r_o^b(\omega)$ whenever $\omega > \omega^o$ and $r_o^g(\omega) > r_o^b(\omega)$ whenever $\omega < \omega^o$. But both inequalities in (Ap.2) hold by Assumption 1. Q.E.D

Proof of Proposition 1: We first derive equation (8). Notice that, if investors (correctly or incorrectly) interpret the policy r_b^o to mean a bad signal, their expectation of inflation, $E[\pi|\Omega] = 0$. Similarly, if they interpret the policy r_g^o to mean a good signal, then they expect inflation to be zero. [This can easily by verified by substituting r_s^o in (7) into equation (5)].

Now, consider a deviation from r_b^o to r_g^o by the policymaker who has received a bad private signal. Then, if investors interpret the deviation as a good signal, the expected payoff of the policymaker will be

$$\begin{aligned} E[V|b, r_g] &= \lambda\left(E[\ln S|b] - E[\ln S|g] + P(G|g)\overline{y}_G + P(B|g)\overline{y}_B\right) \\ &- \frac{\beta^2}{2} P(G|b)\left[\ln G - E[\ln S|g] + P(G|g)\overline{y}_G + P(B|g)\overline{y}_B - \overline{y}_G\right]^2 \\ &- \frac{\beta^2}{2} P(B|b)\left[\ln B - E[\ln S|g] + P(G|g)\overline{y}_G + P(B|g)\overline{y}_B - \overline{y}_B\right]^2 \end{aligned}$$

On the other hand, if the monetary authority follows its signal and implements r_b^o, then its expected payoff is

$$E[V|b, r_b] = \lambda\left(P(G|b)\overline{y}_G + P(B|b)\overline{y}_B\right)$$

$$
\begin{aligned}
& - \quad \frac{\beta^2}{2} P(G|b)(\ln G - E[\ln S|b] + P(G|b)\overline{y}_G + P(B|b)\overline{y}_B - \overline{y}_G)^2 \\
& - \quad \frac{\beta^2}{2} P(B|b)\left[\ln B - E[\ln S|b] + P(G|b)\overline{y}_G + P(B|b)\overline{y}_B) - \overline{y}_B\right]^2
\end{aligned}
$$

Subtracting $E[V|b, r_b]$ from $E[V|b, r_g]$, and using our assumption that $\alpha(\overline{k}_G - \overline{k}_B) = \overline{y}_G - \overline{y}_B - \ln(G/B) = 1$, we get

$$
\Delta(\omega) = E[V|b, r_g] - E[V|b, r_b] = \lambda(P(G|g) - P(G|b)) - \frac{\beta^2}{2}(P(G|g) - P(G|b))^2
$$

as in (8)). It is then easy to see that, if $\phi \to 1$ then

$$
\Delta(\omega)|_{\omega=\frac{1}{2}} = \left[\lambda - (\beta^2/2)\right] \quad \text{and} \quad \lim_{\omega\to 1} \Delta(\omega) = \lim_{\omega\to 0} \Delta(\omega) = (1/2)\left[\lambda - (\beta^2/4)\right].
$$

So by continuity, if $\beta < 2\sqrt{\lambda}$, then there exists $\underline{\omega}$ and $\overline{\omega}$, such that $\Delta(\omega) < 0$ if $\omega \in (\underline{\omega}, \overline{\omega})$, and $\Delta(\omega) > 0$ otherwise. That is, the policymaker will have an incentive to deviate from r_b^o when $\omega < \underline{\omega}$ or $\omega > \overline{\omega}$. Q.E.D

Proof of Lemma 2: The proof is straightforward and follows immediately from equation (5). If investors interpret the policy $r > r_g^o$ as a good signal, then from equation (5),

$$
\begin{aligned}
E[\pi|r > r_g^o] &= r - \frac{1}{\gamma}(E[\ln S|g] - P(G|g)\overline{y}_G - P(B|g)\overline{y}_B) - \ln \alpha E[S|g] \\
&= r - r_g^o
\end{aligned}
$$

using equation (7). Q.E.D

Proof of Proposition 2: (i) Suppose a separating equilibrium exists, in which upon receipt of a bad signal, the central bank sets $r = r_b^o$, but chooses a rate $r > r_g^o$ when the signal is good. The tighter monetary policy $r > r_g^o$ must then satisfy two conditions, as indicated in equations (10) and (11): i.e.,

$$
\lambda(P(G|g) - \omega) - (1/2)(r - r_g^o)^2 \geq 0 \tag{Ap.3}
$$

and

$$
\lambda[P(G|g) - P(G|b)] - (1/2)[r - r_g^o + \beta(P(G|g) - P(G|b))]^2 \leq 0 \tag{Ap.4}
$$

By Propostion 1, we know that (Ap.4) holds for all $\omega \notin (\underline{\omega}, \overline{\omega})$. Now fix $(r - r_g^o)$, and

Now let $\phi \to 1$, then it can easily be shown that $P(G|g) - P(G|b$ is concave in ω, attaining a maximum of 1 at $\omega = \frac{1}{2}$. Hence, if $\beta < 2\sqrt{\lambda}$, then $\Delta(\omega) = \lambda[P(G|g) - P(G|b)] - (1/2)[\beta(P(G|g) - P(G|b))]^2$ is positive, and decreasing in ω for $\omega > \overline{\omega} \geq \frac{1}{2}$; but increasing in ω if $\omega < \underline{\omega} \leq \frac{1}{2}$. Secondly, notice that if $\phi \to 1$, then $(P(G|g) - \omega) \to \frac{1}{2}$ as $\omega \to 0$, but $(P(G|g) - \omega) \to 0$ as ω

approaches 1. Hence, we can find a rate differential $r - r_g^o > 0$, such that the (Ap.4) holds for all $\omega \notin (\underline{\omega}, \overline{\omega})$, but (Ap.3) holds only if $\omega < \underline{\omega}$ or $\omega \in (\overline{\omega}, \omega^*)$, where ω^* solves (Ap.3) with equality, given the choice of $r - r_g^o$. Hence, a separating equilibrium, with $r > r_g^o$ whenever $s = g$, exists for $\omega < \underline{\omega}$ or $\omega \in (\overline{\omega}, \omega^*)$.

(ii) Now suppose $\omega \in (\omega^*, 1)$. In this case, the central bank is unable to use its interest rate policy to influence investors beliefs about the state of the economy. In order to determine whether a pooling equilibrium exists at $r^*(\omega)$, we need to show that the policymaker has no incentive to deviate from $r^*(\omega)$ if a bad signal is observed. [Recall, that $r^*(\omega)$ is the optimal policy if the central bank sees a good signal, but unable to convey this to investors].

Suppose for this range of ω values, investors beliefs about the state of the economy when $r \neq r^*(\omega)$ is given by $\text{Prob}(G|r \neq r^*) = \rho$. Then the optimal deviation when a signal $s = b$ is observed will be the interest rate policy

$$r_\rho(\omega) = \frac{1}{\gamma}\left[E[\ln S_\rho] + \gamma(\ln\alpha + \ln E[S_\rho]) - \rho\overline{y}_G - (1-\rho)\overline{y}_B)\right] + \beta(P(G|b) - \rho) \tag{Ap.5}$$

where $E[S_\rho] = \rho G + (1-\rho)B$.

Now consider a deviation from $r^*(\omega)$ to $r_\rho(\omega)$ when the central bank sees a bad signal about the future path of output. Denote $\Delta_\rho(\omega)$ as the net gain from deviating to $r_\rho(\omega)$. Then, as before, $\Delta_\rho(\omega)$ will be given by

$$\Delta_\rho(\omega) = -\lambda(\omega - \rho) + (\beta^2/2)(P(G|g) - P(G|b))[(P(G|g) - \omega) - (\omega - P(G|b))] \tag{Ap.6}$$

It is easy to show that $(P(G|g) - \omega) - (\omega - P(G|b))$ is negative for $\omega > 1/2$, so that the RHS of (Ap.6) is negative. Therefore, a pooling equilibrium with the interest rate $r^*(\omega)$ can be supported with out-of-equilibrium beliefs given by $\rho < \omega$. That is, a pooling equilibrium with $r = r^*(\omega)$ exists for $\omega \in (\omega^*, 1)$ if investors are less confident of the state of the economy whenever they observe an interest rate policy $r \neq r^*(\omega)$. Q.E.D

References

[1] Athey, Susan, Andrew Atkeson and Patrick J. Kehoe (2003), "The Optimal Degree of Discretion in Monetary Policy," Federal Reserve Bank, Minneapolis, Staff Report #326.

[2] Barro, Robert J. and David B. Gordon (1983a), "A Positive Theory of Monetary Policy in a Natural Rate Model," *Journal of Political Economy*, 91 (4), 589–610.

[3] — (1983b), " Rules, Discretion and Reputation in a Model of Monetary Policy," *Journal of Monetary Economics,*, 12 (1), 101–121.

[4] Blanchard, Olivier (2000); "Bubbles, Liquidity Traps and Monetary Policy: Comments", Manuscript, MIT: http://econ-www.mit.edu/faculty/?prof _id=blanchar

[5] Blinder, Alan (1998), *Central Banking in Theory and Practice*, MIT Press, Cambridge

[6] Canzoneri, Matthew B. (1985), "Monetary Policy Games and the Role of Private Information," *American Economic Review,* 75 (5) 1056–1070.

[7] Caplin, Andrew and John Leahy (1996), "Monetary Policy as a Search Process," *American Economic Review*, 86 (4), 689–702

[8] Cecchetti, Stephen (2002); "Central Bankers and Asset Price Misalignments", Occasional Essay No. 20, Ohio State University

[9] Cukierman, Alex (2000) "The Inflation Bias Result Revisited," Manuscript, Tel–Aviv University, http://www.tau.ac.il/ alexcuk/pdf/infbias1.pdf

[10] Ellingsen, Tore and Ulf Söderström (2001), "Monetary Policy and Market Interest Rates," *American Economic Review*, 91, 1594–1607.

[11] Faust, Jon and Lars E.O. Svensson (2001), "Transparency and Credibility: Monetary Policy with Unobservable Goals," *International Economic Review*, 2, 369–397

[12] Faust, Jon, Eric Swanson and Jonathan Wright (2003), "Do Federal Reserve Policy Surprises Reveal Superior Information about the Economy?" at http://e105.org/faustj/

[13] Garfinkel, Michelle and Seonghwah Oh (1993), "Strategic Discipline in Monetary Policy with Private Information: Optimal Targeting Horizons, *American Economic Review,* 83 (1), 99–117

[14] Gordon, Robert (1997), “The Time–Varying NAIRU and its Implications for Monetary Policy,” *Journal of Economic Perspectives*, Winter, 11–32.

[15] Howitt, Peter (2001), “Learning about Monetary Theory and Policy,” Manuscript, Brown University, at http://www.econ.brown.edu/fac/Peter_Howitt/Learning.pdf

[16] Jensen, Henrik (2003), “Explaining an Inflation Bias without Using the Word ‘Surprise’,” Manuscript, University of Copenhagen

[17] Kuttner, Kenneth (2001), “Monetary Policy Surprises and Interest Rate: Evidence from the Fed Funds Futures Market,” *Journal of Monetary Economics,* 47 (3), 523–544

[18] Kydland, Finn E. and Edward C. Prescott (1977), “Rules Rather than Discretion: The Inconsistency of Optimal Plans,” *Journal of Political Economy,* 85 473–91.

[19] McCallum, Bennett T. (1995), “Two Fallacies Concerning Central Bank Independence,” *American Economic Review, Papers and Proceedings,* 85, 207–211

[20] Orphanides, Athanasios (2001), “Monetary Policy Rules Based on Real–Time Data,” *American Economic Review,* 91 (4), 964–85.

[21] —— (2002), “Monetary Policy Rules and the Great Inflation,” *American Economic Review,* 92 (2), 115–20.

[22] Peek, Joe; Eric S. Rosengren, and Geoffrey M. B. Tootell (1999), “Is Bank Supervision Central to Central Banking?”, *The Quarterly Journal of Economics,* 114, 629–653

[23] —— (2003), “Does the Federal Reserve Possess An Exploitable Informational Advantage?”, *Journal of Monetary Economics,* 50(4), 819–839

[24] Persson, Torsten and Guido Tabellini (1993), “Designing Institutions for Monetary Stability,” *Carnegie-Rochester Conference on Public Policy*, 39, 53–84.

[25] Romer, Christina D. and Romer, David H. (2000), “Federal Reserve Information and the Behavior of Interest Rates,” *American Economic Review*, 90 (3), 429–457

[26] Rudebusch, Glenn (2002), “Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty,” *Economic Journal,* 112, 402-432

[27] Rudebusch, Glenn and Lars Svensson (1999), “Policy Rules for Inflation Targeting”, in John Taylor editor *Monetary Policy Rules* University of Chicago Press.

[28] Staigler, Douglas; James Stock and Mark Watson (1994), "How Precise are Estimates of the Natural Rate of Unemployment?", in Christina D. Romer and David H. Romer, eds. *Reducing Inflation: Motivation and Strategy,* University of Chicago Press.

[29] Svensson, Lars E.O. (1997), "Optimal Inflation Targets, 'Conservative' Central banks, and Linear Inflation Contracts," *American Economic Review,* 87, 98–114.

[30] Swanson, Eric T. (2004), "Federal Reserve Transparency and Financial Market Forecasts of Short–Term Interest Rates," Manuscript, Board of Governors of the Federal Reserve System.

[31] Vickers, John (1999), "Inflation Targeting in Practice: The UK Experience, Center for Financial Studies," Working paper # 1999/02, Frankfurt

[32] Walsh, Carl E. (2002), "When Should Central Bankers Be Fired?" *Economics of Governance*, 3 (1), 1-21

[33] Walsh, Carl E. (2003), *Monetary Theory and Policy*, 2nd. ed., Cambridge, MIT Press.

[34] Wilcox, James (1983), "Why Real Interest Rates Were So Low in the 1970s, *American Economic Review,* 73 (1), 44–53.

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

WORKING PAPER SERIES 2004

ase.tufts.edu/econ/papers

2004-01 EGGLESTON, Karen & Winnie Yipp; Hospital Competition under Regulated Prices: Application to Urban Health Sector Reforms in China

2004-02 EGGLESTON, Karen & Chee-Ruey Hsieh; Health Care Payment Incentives: A Comparative Analysis of Reforms in Taiwan, Korea and China

2004-03 EGGLESTON, Karen; Competition, Altruism, and Provider Payment

2004-04 LOURY, Linda; Some Job Contacts are More Equal Than Others: Earnings and Job Information Networks

2004-05 LOURY, Linda; Teen Childbearing and Community Religiosity

2004-06 LOURY, Linda; Religiosity and High School Misbehavior

2004-07 MUKAND, Sharun & Sumon Majumdar; Policy Gambles

2004-08 MUKAND, Sharun & Sanjay Jain; Public Opinion and the Dynamics of Reform

2004-09 MUKAND, Sharun, Sumon Majumdar & Anandi Mani; Politics, Information and the Urban Bias

2004-10 BIANCONI, Marcelo; Aggregate and Idiosyncratic Risk and the Behavior of Individual Preferences under Moral Hazard

2004-11 BIANCONI, Marcelo; Transfer Programs and Consumption under Alternative Insurance Schemes and Liquidity Constraints

2004-12 BIANCONI, Marcelo; Heterogeneity, Adverse Selection and Valuation with Endogenous Labor Supply

2004-13 BIANCONI, Marcelo; The Welfare Gains from Stabilization in a Stochastically Growing Economy with Idiosyncratic Shocks and Flexible Labor Supply

2004-14 SHIMSHACK, Jay P. and Michael B. Ward; Enforcement and Environmental Compliance: A Statistical Analysis of the Pulp and Paper Industry

2004-15 NORMAN, George and Joel P. Trachtman; The Customary International Law Supergame: Order and Law

2004-16 BROWN, Drusilla K. and George Norman; Optimal Intellectual Property Rights Protection and Humanitarian Assistance during and International Health Emergency

2004-17 LOURY, Linda; Job Tenure and Personal Contacts: Good Matches or Limited Choices?

2004-18 KUTSOATI, Edward and Sharun Mukand; Expectations and the Central Banker: Making Decisions the Market Expects to See?

2004-19 RICHARDS, Daniel; Price Discrimination and the Long Boom.

2004-20 HARDMAN, Anna and Yannis Ioannides; Income Mixing and Housing in U.S. Cities: Evidence From Neighborhood Clusters of the American Housing Survey.

2004-21 HARDMAN, Anna and Yannis Ioannides; Neighbors' Income Distribution: Economic Segregation and Mixing in US Urban Neighborhoods. [revised]

2004-22 EGGERS Andrew and Yannis Ioannides; The Role of Output Composition in the Stabilization of the U.S. Output Growth

2004-23 SHIMSHACK Jay; Are Mercury Advisories Effective? Information, Education, and Fish Consumption.