MAKING MONETARY POLICY: OBJECTIVES AND RULES

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What is it that monetary policy-makers do and how do they do it? The simple answer is that a central banker moves interest rates in order to maintain steady real growth and stable prices. In this essay, I examine the issues that arise in framing the problem faced by monetary policy-makers. I begin with a discussion of how, over the past decade or so, central banks have been made more independent and more accountable. The result has been the virtual elimination of the inflation bias problem that is caused by political interference in the monetary policy process, and better overall macroeconomic performance. The essay proceeds with an example of a formal version of the policy-makers' problem, describing their objectives and the information they need to formulate a policy rule. I conclude with a discussion of simple versus complex policy rules, the impact of uncertainty on policy-making, and how central bankers use formal modelling in making their day-to-day decisions.

I. INTRODUCTION

Over the past century, the prominence of central banks has steadily increased, to the point where hardly a day goes by without some mention of monetary policy-makers appearing in the headlines. There is continuous speculation about the likely future actions of the worlds' central banks. Newspapers are filled with stories about the decisions to be taken by central banks in both the G7 and the emerging markets. What is it that monetary policy-makers do, and what accounts for their prominence in our daily lives?

Central bankers control interest rates in an effort to stabilize output and inflation. Changes in interest rates affect most of us directly through increases or decreases in the cost of borrowing, while stable prices and steady real growth make our economic and financial planning much easier.

In most countries today, the central bankers are the only governmental authorities engaged in stabilization policy. Economists and policy-makers now agree that fiscal policy, once thought to be capable of helping to smooth fluctuations in real growth, is not up to the task. Central banks are the sole remaining policy-making bodies thought capable of reducing business-cycle fluctuations.

How should we think about the central banker's problem? The answer is relatively simple. Policy is, or should be, the solution to a complex control problem, similar in structure to the one faced by an airplane pilot. A pilot's objective is to use the plane's controls, given knowledge of the weather and the wind, to fly from one city to another. Similarly, a monetary policy-maker's objective is to move interest rates, given knowledge of how the economy evolves, to maintain steady real growth and stable prices. In engineering, problems of this type are called *optimal control problems*, and they involve minimizing an objective or loss (the weighted sum of inflation and output variability) subject to the evolution of the state (the economic structure describing the paths of output and inflation) to yield a control rule (the monetary policy rule describing the reaction of the interest-rate instrument).

This engineering approach yields what most people would call a *policy rule*. That is, monetary policy-makers will have a rule in which the short-term interest rate reacts to observable measures of current economic activity. Much of the research into the normative question of how monetary policy should be made focuses on how best to formulate these systematic rules. Taylor (this issue) refers to this as 'the new normative macroeconomics.'

The purpose of this essay is to examine issues that arise in framing the central banker's problem. I will outline and comment on the policy-maker's control problem in several steps, beginning with a very brief description of recent developments in the conduct of monetary policy and how institutions have been redesigned over the past decade. Central banks have been made independent and accountable for meeting specific objectives, leading to the elimination of the inflation bias that arises from political interference in the monetary policy process. A description of the source of the inflation bias and the solution is the topic of section III. This provides a backdrop for the detailed examination of monetary policy objectives contained in section IV. Next, in section V, I present an explicit example of a problem with its solution, and discuss the general properties of the resulting policy rules. Even this relatively simple model is quite useful, and in section VI, I take up a discussion of the simple versus more complex policy rules and the Taylor rule. Section VII addresses the all-important issue of monetary policy-making under uncertainty. How is it that policy-making is affected by imperfect knowledge of various kinds? In the final section, I provide a brief discussion of how it is that modelling is used by central bankers in making their day-to-day decisions.

II. RECENT DEVELOPMENTS IN THE CONDUCT OF MONETARY POLICY

During the 1990s, there was a convergence around the world in the goals and methods used to conduct monetary policy. A number of forces are responsible for this development. First, during the 1970s and 1980s, many countries experienced very high levels of inflation, and prices rose well in excess of 50 per cent per year for extended periods.[2] This led to a clear consensus that even moderate levels of inflation damage real growth and that low inflation must therefore be a primary objective of monetary policy. Casual observation suggests that low-inflation countries experience higher growth rates, and so there are strong incentives to devise ways in which to keep inflation low.[3]

Second, evidence indicates that in most countries, short-run money demand functions are unstable and that meaningful measures of money, such as M2 or M3, are very difficult to control.[4] As a result,

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[2] Examples include Bolivia, Israel, and Argentina.

[3] The literature on the connection between inflation and growth is large and growing. Barro (1996) and Andrés and Hernando (1999) are recent examples.

[4] The case for the United States is made in Cecchetti (1995*b*). Browne *et al.* (1997) make the same point for the individual countries of the European Union and go on to suggest that money demand may be more stable in the European Union as a whole than it is in the individual countries of Europe.

monetary targeting alone is no longer viewed as a viable strategy for stabilizing prices. Finally, excessive exchange-rate volatility is seen as damaging. The discussion about the appropriate exchange-rate regime is ongoing, but a number of countries have organized their policy framework with the goal of reducing or eliminating fluctuations in the value of their currency relative to that of some anchor country. Since these anchor countries typically have low inflation, this strategy calls for maintaining similar low rates.

As consensus has grown on these issues, many countries have redesigned their central banks and, for the most part, achieved remarkable reductions in inflation.[5] A survey of 77 countries reported in Fry *et al*. (1999) divides countries into three groups on the basis of their monetary policy regime: exchange-rate targeting, monetary targeting, or inflation targeting. The recent trend clearly favours explicit or implicit inflation targeting. At least seven countries now set explicit inflation targets that clearly dominate any other targets or objectives. These countries are: New Zealand, which in 1988 became the first industrialized country to adopt an explicit 'hard' inflation target; Canada, Chile, and Israel, which adopted inflation targeting in 1991; the United Kingdom which moved to explicit inflation targets in 1992; and Australia and Sweden, which changed their policy frames in 1993. Fry *et al*. list a total of 45 countries that, over the past decade, have adopted some form of inflation target: 12 industrialized, 12 transitional, and 21 developing.[6] Similarly, many other countries have changed their monetary regimes to target monetary aggregates or exchange rates with the goal of creating a credible low inflation policy.

III. AVOIDING THE INFLATION BIAS

Today, the central banks of the world share several common features. First, for the most part, they are independent. As noted by King (1999), this is a relatively recent phenomenon. In fact, only in the last few years were the Bank of England and the Bank of Japan granted independence from their finance ministries when taking interest-rate decisions.

At first glance, the granting of independence to a governmental institution as powerful as a central bank seems odd. In fact, as Blinder (1997) has pointed out, there is a potential conflict between central bank independence and representative democracy. Since one of the crucial elements of a democratic society is that powerful policy-makers are accountable to the people, how can we square accountability with independence? The answer is that independent central banks are generally given clear objectives and then held publicly accountable for meeting them.

The evidence is now overwhelming that independent, but accountable, central banks yield better overall policy and macroeconomic outcomes. The changes have worked. As Cecchetti and Krause (2001) discuss in detail, the variability of both inflation and output are lower today than they were a decade ago. The reason is largely improvements in the efficiency with which policy-makers have been doing their jobs.

Nearly 20 years ago, Barro and Gordon (1983) noted that if a policy-maker cannot credibly commit to a zero inflation policy, then even if he or she announces that inflation will be zero, and all private decisions are based on the assumption that inflation will in fact be zero, it is in the policy-maker's interest to renege and induce an increase in the aggregate price level. The reason for this is that at zero inflation the value of the increase in output obtained from fooling private agents and creating a transitory increase in output (along a Phillips or Lucas supply curve) more than offsets the cost of the higher inflation, and so the claim of zero inflation in the absence of commitment is not credible. In the language of optimal control, a zero inflation policy is not dynamically consistent.

Since the problem is most severe when potentially short-sighted legislators are capable of influencing

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[5] Mishkin (1999) provides a discussion of recent international experience with various monetary regimes. Anderson and Wascher (1999) summarize the recent inflation experience in the industrialized countries.

[6] In their Table 4.1, Panel C, Fry *et al*. also identify 34 countries that target primarily money and 36 that target exchange rates.

central bank policy directly, the prominent solution has been to create independent central banks. It is commonly thought, and the data confirm, that policy-makers who are more independent are better able to make credible commitments to low-inflation policy.[7]

There is some dispute over the seriousness of the inflation bias problem. Blinder (1997) notes that it is in the interest of the central bankers to build a reputation for credibility over time, and that the inherently repetitive nature of policy-making minimizes this problem. That is, since policy is made repeatedly, it is straightforward to hold monetary policy-makers to account for their prior statements, and so their actions become credible (or not) fairly rapidly. This position is relatively easy to hold for someone sitting in the United States, where the Federal Reserve has been independent since 1914 and relatively free of meddling from elected legislators since at least 1979. But in most other countries, there is a long history of central bank policy being run to benefit spendthrift politicians. Such political interference makes it almost impossible for central bankers to create an environment in which their policy statements are believed.

But the theory tells us that independence alone is not enough. An inflation bias arises primarily from the desire of policy-makers to drive output growth above its sustainable or natural rate. For this reason, it is crucial that central bankers not only be independent of political pressure, but be committed to maintaining output growth at its sustainable rate. Various methods have been suggested for insuring accountability to such a commitment. At one extreme is Walsh's (1995) proposal that central bankers be given contracts, and that they be fired for failure to perform. Less draconian alternatives include the recently instituted requirement that the Governor of the Bank of England write a letter to the British Chancellor of the Exchequer if inflation deviates by more than one percentage point from the Chancellor's target. Regardless of the method, though, avoiding the inflation bias problem requires some combination of independence and accountability.

IV. THE OBJECTIVES OF MONETARY POLICY

An accountable central bank is one with clearly articulated and publicly stated objectives. So far, we have discussed how it is that monetary policy must not attempt to drive output above its potential. We also know that the primary objective of many central banks is to stabilize prices. In fact, central banks generally stabilize some combination of inflation, output, and interest rates. Why do they do this? As a first step in formulating the monetary policy-maker's control problem, this section is devoted to a detailed discussion of the justifications for including price stability, output stability, and interest-rate stability as objectives for central bankers.

Before beginning, it is worth making a small digression into the issue of exchange-rate stabilization. I argue below that it is appropriate to derive a monetary policy rule by minimizing a loss function that includes only output and inflation, and not exchange rates (or interest rates). The basis for this is my belief that domestic inflation and output are the fundamental concerns of policy-makers. The decision to focus on the exchange-rate path in the formulation of policy is the choice of an instrument, or intermediate target, not an objective. Under normal circumstances, policy-makers should not be concerned with the volatility of the exchange rate *per se*, but with the domestic inflation and growth outcomes produced by the path they choose for their instrument to follow. Exchange-rate targeting is analogous to monetary-aggregate targeting. It is a means to an end, not an end in itself.

With this in mind, now return to the task at hand—the formulation of an objective for monetary policy. In the remainder of this section, I will discuss various reasons we might ask central banks to stabilize prices and output. I will also discuss at some length why it is that they smooth interest rates, and how this is a consequence of their actions, not an objective in and of itself.

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[7] Alesina and Summers (1993) establish this empirically and raise the additional possibility that countries with independent central banks not only have lower steady inflation, but also less variable output and higher growth. Cukierman *et al*. (1993) also investigate the impact of central bank independence on the growth rate of output.

(i) Stabilizing Prices

The costs of inflation
Why do we care about inflation? I have asked this question of many people who are not trained in economics. The most common response, and the one that I believe accounts for general public dissatisfaction with inflation, is that inflation is *responsible* for declines in real income. In recent experience, high price inflation has not been accompanied by equal wage inflation. The perception of most people is that price inflation is somehow responsible for the real wage declines that result. They are blaming inflation for the effect of negative supply shocks, such as oil price increases, that essentially reduce the level of domestically consumable GNP. But this has nothing to do with inflation itself. Inflation is the equiproportional change in all nominal prices and wages, not the change in any particular relative price.

But public dissatisfaction with inflation is very real. I am unwilling to accept that people are so stupid that the primary reason they care about it—the belief that it *causes* real income reductions—is specious. So why is everyone so upset about inflation? What other costs of inflation can we identify? I will now list a few, closing with the one I believe to be the most convincing, that high inflation is inherently unstable.

One cost of inflation is the tax on the money that we hold. More specifically, it is a tax on the monetary base. But the monetary base, currency plus reserves, is quite small, and so the tax is really very modest. The inflation tax is the erosion in the value of the monetary base caused by inflation, scaled by the size of the economy. This is just the level of the base times inflation, relative to nominal GNP.

Take the current US case as an example. In autumn 2000, the monetary base of the USA was in the order of $600 billion,[8] and nominal GDP was just under $10 trillion. With inflation of 2½ per cent, this means that the inflation tax was about $15 billion, or 0.15 per cent of GDP per year. But not all US currency is held by Americans. Estimates are that nearly three-fourths of US currency is abroad, and

so a significant part of the inflation tax is borne by foreigners who choose to hold US currency. The portion paid by US residents is about one-third of this, or 0.05 per cent of GDP, only $5 billion or $20 per capita per year. This cannot be the primary cost of inflation, or we simply would not care about it.

A second cost of inflation relates to taxes. The tax system in most countries is not properly indexed, and so there are welfare losses associated with inflation. In particular, the failure accurately to index taxes on capital gains leads to under-investment and a capital stock that is too small. Overall, then, an economy with inflation will have a permanently lower level of output. The papers in Feldstein (1999) show that these effects can be quite substantial, and so it may be worth paying a fairly high price to reduce inflation to near zero.

Beyond tax distortions, inflation creates noise in the price system. That is, when there is aggregate price inflation, it becomes more difficult to discern changes in relative prices. Movements in one price relative to another are the basis for resource allocation. When this system is damaged, allocations become less efficient and the economy does not operate as smoothly as it could. It is very difficult to get a sense of the scale of this cost, but it seems likely to be fairly small.

Yet a fourth cost of inflation is that at high levels of inflation, people tend to invest substantial time and effort into finding ways to reduce its costs. Several examples come to mind. First, in countries that experience inflation in the range of 100+ per cent per year, the financial sector grows out of proportion with the rest of the economy. There are too many banks, too many short-term and indexed financial instruments, and too much overall energy put into monitoring the value of one's money. Second, retailers of durable goods must find ways to change prices that are relatively low cost. This usually involves investment in information technology that would otherwise be unnecessary.

Finally, there is the empirical fact that high inflation is uncertain inflation. Looking around the world, we cannot point to any examples of high and steady

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[8] This is an astonishingly large number, representing roughly $2,000 of currency per member of the US population.

inflation. Instead, when inflation rises, there is an increase in uncertainty of future inflation. The costs of this are potentially quite high, as it makes long-term planning more difficult. Both individuals formulating retirement plans and companies making investment decisions face difficult problems when confronted with uncertainty about the path of future prices.

This last point is very much at the heart of the problem. If we could have high and stable inflation, some of the costs would go away. A guaranteed level of say 10 per cent inflation per year, with only small deviations, might probably promote adjustment in the tax code and the like that would reduce the costs. But there are two things wrong with this line of reasoning. First, the fact that we should not have to pay to move to a world with a high steady inflation rate, and second the firmly held belief that high inflation policies are not credible.

Overall, central bankers now agree that the costs of inflation are high, and that variable inflation entails significant social losses. As a result, the primary objective of monetary policy, and the one that appears to be within the grasp of the policy-makers, is to stabilize inflation about a level that is low enough that it becomes irrelevant for household and firm decision-making.

The only remaining question then is what level of inflation should be the target. The answer to this is still the subject of substantial debate. Cecchetti and Groshen (forthcoming) address the issue of how to choose an optimal inflation rate. We note that when prices adjust infrequently, inflation distorts price signals and leads to resource misallocations. But if wages and prices are rigid downward, some amount of inflation facilitates adjustment to real shocks. Recent research has produced measures of the relative size of these costs and benefits in an economy that suggest that inflation targets between zero and 2 per cent, after adjusting for the known upward bias in traditional price indices,[9] are optimal.

Price-level versus inflation stabilization

Before we move on to discuss the arguments for including output stability in the central bank's objective, it is worth addressing one more subject that has attracted increasing attention in recent years. Should policy target the inflation rate or the path of the aggregate price level?[10]

Price-level and inflation targeting have very different implications for the time-path of the variance of prices. Level targeting implies more volatile short-horizon prices and less volatile long-horizon prices than does rate targeting. To see why, consider the simple case of a zero inflation target. With price-level targeting, a positive inflation shock today means that the central bank must bring inflation below zero sometime in the near future. In time, deviations from the target path for the price level disappear completely.

With inflation targeting, bygones are bygones, and so the same positive shock is followed by a simple reversion of inflation to zero, resulting in a permanently higher price level. This *base drift* means that, in an inflation-targeting regime, variance of the price level grows with time..

A recent paper by Gaspar and Smets (2000) discusses the relative merits of price-level versus inflation stabilization in detail. Depending on the structure of the economy, and especially on the persistence of output deviations from trend, price-level targeting may result in a lower variance of prices, without an increase in the variance of output. In general, it appears that a partial reversion to the price-level is warranted.

King (1999) describes why he believes that the distinction between price-level and inflation-rate targeting is irrelevant in practice. He plausibly suggests that if a central bank is held to an inflation target on average over a relatively long horizon of 10 years or so, then it becomes a price-level target. The logic is straightforward. Consider an inflation target

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[9] See Shapiro and Wilcox (1996) for a survey and discussion of the literature on inflation measurement bias.

[10] This issue has been studied recently by Svensson (1999*a*), Dittmar and Gavin (2000), and Vestin (2000). The result, described very nicely in Parkin (2000) is that if output is sufficiently persistent, then price-level targeting yields the same output variability but lower inflation variability than does inflation targeting.

of 2 per cent on average for a decade. Asking whether the monetary policy met this target is the same as asking whether the price level is close to $1.02^{10} = 1.22$ times where it was 10 years earlier. The deviation of 10-year inflation from 22 per cent would be a measure of the success of the policy. This is price-level targeting.

King's observation that inflation and price-level targeting are really the same at long horizons has important implications for the behaviour of both prices and policy-makers. First, even with inflation targeting, the variance of the price level is unlikely to increase without bound. Instead, this variance will peak at some medium-term horizon at which policy-makers will feel constrained to bring prices back to the path implied by the target. Second, policy-making will be driven by a constant desire to bring prices back to this same path so that inflation averages the target level over a long horizon.

Overall, we can conclude that there is a convincing argument for price stabilization. Only two issues remain unresolved. First, should we allow for base drift, or insist on targeting the price level? And second, should we target zero inflation or should the target be slightly positive? Beyond these questions, things are basically resolved.

(ii) Stabilizing Output

Is it desirable for policy to attempt to stabilize output? In 1987 Robert Lucas estimated that elimination of the post-Second-World-War variability in US consumption would have the same welfare impact as an increase in consumption of something like one-tenth of one percentage point. As I write this in the autumn of 2000, per capita US consumption is approximately $24,500, implying that we would be willing to pay slightly less than $25 a piece (annually) to eliminate business cycles.

Lucas proposes

taking these numbers seriously as giving the order-of-magnitude of the potential marginal social product of additional advances in business cycle theory—or more accurately, as a loose upper bound, since there is no

reason to think that eliminating *all* consumption variability is either a feasible or desirable objective of policy. (Lucas, 1987, p. 27)

Furthermore, implementation of an activist policy always risks destabilizing the economy.

There are two counters to Lucas. The first is that the burden of business cycles is very unequal across the economy, and so in the interests of equity we may wish to do something about it.[11] But the second response is more powerful: volatility and growth are related. That is, a stable economy grows more rapidly. Ramey and Ramey (1995) present evidence that, in a broad group of 95 countries, there is a strong negative correlation between volatility and growth. They go on to suggest that the source of this may be the fact that firms are more likely to engage in long-lived investment projects, whose pay-offs may be spread over many years, if they believe that the world is a stable place.

What Ramey and Ramey find to be true across countries on average over long historical periods also seems to be true within a country over time. McConnell and Perez-Quiros (2000) provide some interesting evidence for the USA on the relationship of growth to volatility. They show that there has been a dramatic reduction in the volatility of real US GDP since 1984, and go on to attribute the break to changes in inventory management policies. Taylor (1999a) notes the same fact about volatility, but ascribes it to improved monetary policy. Regardless of the cause, the fact is that the lower variability of output has come with a steady increase in the sustainable growth rate of the economy, suggesting that Lucas's simple calculations are not the end of the story.

Overall, including a role for output stabilization in central bank objectives seems prudent. The only issue is how important should it be relative to price stability when formulating the objective. Here, the answer is that it may not matter. As Svensson (1999a) has pointed out, the more important output variability is in the policy-maker's objective function, the slower the return of inflation to its target. That is, the longer the horizon over which the policy-

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[11] It is not at all clear that this is an rationale for macroeconomic stabilization. Instead, this argues for labour-market policies that create some sort of income insurance.

maker is expected to meet the inflation objective, the more importance is implicitly being attributed to output in the loss function.

The Svensson result is very intuitive. If the policy-maker is faced with a short-run trade-off between stabilizing output and stabilizing inflation, the longer the horizon over which inflation can be stabilized the more scope there is for short-run output stabilization.

(iii) Stabilizing Interest Rates

Central banks tend to change their policy instrument in sequences of small steps, generally continuing in the same direction. Reversals are much less frequent. Looking at interest-rate data, we see that there is substantial inertia. Goodhart (1999) presents evidence that in both the USA and the UK interest-rate changes are very persistent. That is, there are too many 'continuations' of policy changes in the same direction, relative to what would be predicted by any sort of sensible model of monetary policy actions. Sack and Weiland (1999) come to a very similar conclusion when they note that from 1984 to 1998, 85 per cent of the movements in the Federal Funds rate represent continuations.

Where does this interest-rate smoothing come from? There are several possible explanations. One is that the central bank takes it as an explicit objective to keep interest rates smooth in order to insure financial stability. It is impossible to have macroeconomic stability without financial stability, and so it is entirely reasonable that the central bank should take actions to insure that the chances of financial crises are kept to a minimum.

Is it really true that sudden large jumps in the policy instrument are somehow disruptive of financial markets? Yes, but only if financial markets are relatively certain that it will never happen. So, if they expect it, you have to do it. But if market participants realize that new information can precipitate large and sudden interest-rate changes, then they will build institutions that can withstand the potential disruptions this would otherwise cause. The only reason that people believe smooth interest rates enhance financial stability is because interest rates have been smooth.

Yet another explanation for why policy-makers should stabilize interest rates is that smooth interest rates enhance credibility. But the reasoning behind this explanation seems defective as well. Large interest-rate movements only harm central bankers' credibility if their actions cannot be adequately explained. But someone who cannot explain what they are doing will not be credible regardless of how smooth is the path of the policy instrument.

Sack and Weiland (1999) examine three substantially more plausible explanations for interest-rate smoothing. The first is forward-looking expectations. If agents are forward looking, then the expectation that small initial policy movements will be followed by additional moves in the same direction increases the impact of any given policy change. Sack and Weiland's second explanation is based on data uncertainty. Moderate responses to changes in measured output and inflation may be warranted when policy-makers have imperfect knowledge of the state of the economy. And third, there is uncertainty about parameters of the model. When the central bank is unsure about the impact of an interest-rate movement, they will act more prudently and respond gradually to changes in the environment in order to assure that unintended volatility is not introduced into the system. I return to these last two points in section VII.

My conclusion is that the objective of monetary policy should be the stabilization of the domestic economy through the reduction in the variability of prices and output growth. Optimal policy may entail interest-rate smoothing, but there is no justification for this to be an explicit objective.

V. A SIMPLE ANALYTICAL FRAMEWORK: FINDING THE POLICY RULE

A framework for analysing this problem has two components: the objective function to be minimized and the structure of the economy that acts as a constraint on behaviour. We consider each of these, and then discuss the solution to the problem that is the policy rule.

(i) The Objective Function

The simplest, and most commonly used, objective function assumes that the policy-maker seeks to minimize the squared deviations of output and prices from their target paths. The general form of such a loss function (measured over a medium-term horizon of 3 or 4 years) can be written as

$$L = E[\alpha\pi^2 + y^2], \tag{1}$$

where E denotes the mathematical expectation, π is the deviation of inflation from its target, y is the the (proportional) deviation of aggregate output from its 'potential', or full capacity, level, and α is the weight given to squared deviations of inflation from its desired level.[12] The parameter α is the crucial quantity of interest, and we will call it the policy-maker's inflation variability aversion. When α tends to infinity the policy-maker cares only about inflation, and when α tends to zero (s)he cares only about output.

It is worth making one technical comment about equation (1). As I have written it, the objective function is symmetrical, including only quadratic terms. The implication is that policy-makers care equally about extreme positive and extreme negative events. This is surely not the case: we would expect policy-makers to take action when the mean and variance of forecast distributions are likely to stay the same, while the probability of some extreme bad event increases. That is, even if the variance is unchanged, an increase in the possibility of a severe economic downturn is likely to prompt action. Nevertheless, we will continue with this simple functional form, as anything more complex is unlikely to be mathematically tractable.

(ii) The Structure of the Economy

The second component of the analytical framework is a set of linkages among the economic quantities of interest. This is a structural economic model, and

such models are potentially very complex. The more involved the structural model of the economy, the more difficult it will be to find the optimal policy rule for the monetary authority, and the more complicated that rule will be. As a result, I will examine the policy-maker's problem using the simplest set-up that is capable of delivering the primary lessons about monetary policy rules.

The minimum requirement is a set of relationships linking deviations of the log of output from its potential level (y), the deviation of inflation from its target (π), and the interest-rate instrument (r), which here is taken to be the real interest rate.[13]

Crucial for the purpose here is that there are two kinds of disturbances buffeting the economy and that require policy responses. The first shock—the aggregate demand shock (d)—moves output and inflation in the same direction; the second shock—the aggregate supply shock (s)—moves output and inflation in opposite directions. Policy is only capable of moving output and inflation in the same direction, and so is analogous to an aggregate demand shock.

A simple textbook aggregate demand and aggregate supply is sufficient for the task at hand. Following Bean (1998), write the aggregate demand and aggregate supply curves as

$$y = -\lambda r + d \tag{2}$$

and

$$\pi = \omega y + s, \tag{3}$$

where ω is the slope of the aggregate supply function and λ is a constant. Any dynamics in aggregate supply are suppressed for simplicity: I assume that policy is credible and so that inflation is always near its target, in the way suggested by equation (3).

After substituting output, equation (2), into the aggregate supply curve (3), we obtain the simple reduced form relations

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[12] This loss function can be written in a more complex, dynamic form in which a discount factor and a time horizon appear explicitly.

[13] As is standard in simple models of this kind (see, for example, Bean, 1998), I measure the interest-rate instrument in deviations from the equilibrium value that it would need to have in order that output be equal to its potential level. To treat the real interest rate as the instrument of monetary policy is a simplification, but, in the sticky-price world being examined here, all that is needed for this is that the monetary authorities change the interest rate sufficiently often, and sufficiently decisively, to remain 'ahead of the game'. That is, I assume that they are able to change the nominal interest rate enough to prevent changes in inflation expectations from sabotaging the way in which they want the real interest rate to respond to conditions in the economy.

$$y = -\lambda r + d \qquad (4)$$

and

$$\pi = -\omega\lambda r + \omega d + s. \qquad (5)$$

(iii) The Policy Rule

The quadratic objective and linear economic structure means that the optimal policy response to demand and supply shocks is a simple linear rule. That is, the instrument response is of the form

$$r = ad + bs, \qquad (6)$$

where a and b are the degree to which policy reacts to the two shocks.

Minimizing the loss, subject to the constraint imposed by the structure of economy, yields optimal values for the reaction parameters a and b. Call these a^* and b^*. The result is that policy offsets aggregate demand shocks one-for-one, and so a^* is equal to λ^{-1}.

The response to supply shocks is more complex, as they create a trade-off for policy. Faced with a shock that moves inflation but not output, and an instrument that moves them both, the policy-maker must make a choice. Stabilizing either output or inflation, destabilizes the other, creating the output–inflation variability trade-off. The extent of the reaction to a supply shock then depends on the policy-maker's aversion to inflation variability (α), as well as the slope of aggregate supply, measured by ω. The loss-minimizing solution for b is given by

$$b^* = \frac{\alpha\omega}{\lambda[\alpha\omega^2 + 1]}. \qquad (7)$$

The form of b^* is what one might expect. For example, when $\alpha \to \infty$, as it would for an extreme form of inflation targeting, then $b^* = (\omega\lambda)^{-1}$, implying that a negative supply shock precipitates an interest-rate increase the purpose of which is to keep inflation from rising. At the other extreme, $\alpha = 0$ and $b^* = 0$ implies no policy response to a supply shock, thereby stabilizing output and allowing

inflation to rise or fall. For intermediate values of α, the response is somewhere between these extremes.

The optimal policy has several implications for the variability of output and inflation. In particular, both depend only on the variance of aggregate supply shocks, not on the variance of demand shocks.[14] This follows immediately from the fact that the optimal policy rule dictates that demand shocks be offset completely by interest-rate moves.[15] Second, changes in the volatility of aggregate supply shocks shift the variance of output and inflation in the same proportion.

As a result, we can derive the following ratio:

$$\frac{\sigma_y^2}{\sigma_\pi^2} = [\alpha\omega]^2. \qquad (8)$$

This expression has several interesting properties. First, note that when $\alpha = 0$ (the policy-maker cares only about output variability), $\sigma_y^2/\sigma_\pi^2 = 0$. Likewise, for $\alpha \to \infty$ (the policy-makers cares only about inflation variability), $\sigma_y^2/\sigma_\pi^2 \to \infty$. Significantly, varying α between zero and infinity allows us to trace out the entire output–inflation variability frontier, the shape of which is related to the slope of the aggregate supply curve ω and is unaffected by either the slope of the aggregate demand curve or the variance of aggregate supply shocks.

(iv) Interpretations

This simple framework can be used to help understand a number of points that have been raised in the recent debate over the conduct of monetary policy. I will comment on three: alternative targeting regimes, target rules versus instrument rules, and inferring policy-makers' preferences. In section VI, I take up a discussion of simple versus complex policy rules, and the Taylor rule.

Alternative targeting regimes
Given the optimal control view of the policy-maker's problem, how can we interpret the current

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[14] The resulting expressions are $\sigma_y^2 = (b^*\lambda)^2\sigma_s^2$ and $\sigma_\pi^2 = (1 - \lambda\omega b^*)^2\sigma_s^2$, where σ_s^2 is the variance of the supply shocks and b^* is the optimal reaction to s_t in equation (7).

[15] If the policy-maker can only respond to demand shocks with a lag, then it will no longer be possible to neutralize them completely. Instead, policy will only be able to eliminate the future effects of current shocks. This will complicate the trade-off between output and inflation. See Bean (1998) for a discussion.

debate over the proper choice of a policy target, or the advisability of targeting in general? Commonly mentioned targets—for example, inflation and nominal income—are not control variables for the central bank, and so how might we approach this question? There are two ways of addressing the issue of targets. The first is purely technical, and the second has to do with the way in which policy-makers might portray their intention to the public. Technically, the first-order conditions to the optimal control problem may be interpreted as producing a type of targeting regime. To see this, consider the case examined in detail by Svensson (1997). He examines pure inflation-rate targeting where the loss is independent of output variation, i.e. the case which is equivalent to $\alpha \rightarrow \infty$. The first-order condition of this problem implies setting the path for expected inflation as close to the target value as possible. Svensson refers to this as 'inflation forecast targeting'. More generally, any dynamic control problem implies a relationship among endogenous variables that holds along an optimal path—the equivalent to the statement that the expected inter-temporal marginal rate of substitution in consumption equals the risk-free (real) interest rate.

Nominal income targeting does not naturally arise from the loss function (1). The reason is straightforward. Nominal income targeting would be an attempt to keep $(p_t + y_t)$ close to zero. This suggests a loss function with terms of the form $(p_t + y_t)^2$. That is, the policy-maker would be instructed to be averse to squared deviations of *nominal* income from its optimal path. There are three differences between this and the loss function written as the weighted sum on output and inflation variability. First, the weights need not be equal, and so α may differ from one. Second, nominal income targeting is based on the behaviour of the path of real output and the price level, and so will in general be inconsistent with inflation targeting. Finally, and most importantly, even if $\alpha = 1$, nominal income targeting implies caring about a covariance term of the form $p_t y_t$ that does not appear in (1). Inclusion of this covariance term means that policy-makers will not care about equal and offsetting deviations of price level and output from their targets. Under nominal income targeting, price level and real errors with correlation

minus one are costless. It is difficult to see why constant nominal income, with volatile prices and output, would be desirable.

It is worth digressing briefly to comment on where intermediate targets fit into this scheme. Over the last half-century or so, many monetary economists have advocated targeting various monetary aggregates.[16] Researchers do not claim to care about money for its own sake, nor do they claim that central banks can control it exactly. Therefore, monetary aggregates are neither a direct objective nor an instrument. Instead, they are somewhere in between. They are *intermediate* targets.

I find it difficult to make a coherent argument for intermediate targets. To see why, consider the case in which the policy-maker controls an interest rate, cares about inflation, and uses M2 as an intermediate target. To control the objective, the policy-maker must know how inflation responds to changes in the exogenous environment (the response of π_t to s and d) and how the objective responds to changes in the instrument. But how does an intermediate target such as M2 help? Clearly, if the relationship between interest rates and M2 and that between M2 and prices are both stable and precisely estimable, then there is no advantage to looking at the two relationships separately. There may be some cases in which estimating the impact of interest rates on M2 and the impact of M2 on prices separately gives a more reliable estimate of the product of the two, but such instances would surely be rare. If M2 helps forecast prices, then it will be included in the model. But there is substantial evidence, some of which is in Cecchetti (1995b), that reduced-form inflation forecasting relationships are very unstable, even if they include M2, or any other potential intermediate target.

As a result, the only case I can see for intermediate targeting is that it contributes to policy transparency. To quote Svensson (1999b), the ideal intermediate target

is highly correlated with the goal, easier to control than the goal, easier to observe by both the central bank and the public than the goal, and transparent so that central bank communication with the public and public

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[16] For a recent discussion of M2 targeting, see Feldstein and Stock (1994).

understanding and public prediction of monetary policy are facilitated. (pp. 14–15)

Monetary aggregates seem particularly poorly suited to such a task.

Target rules versus instrument rules
Svensson's (1999*b*) distinction between a *target rule* and an *instrument rule* is also useful here. As he defines it, an instrument rule is a relationship between the control variable and the observable state—equivalent to (6). So, an instrument rule is a statement that the interest rate will be raised or lowered by a specific amount following aggregate demand or aggregate supply shocks of a certain size. By contrast, the statement that the policy-maker adjusts the instrument such that inflation and/ or output will follow a certain specified path is a target rule. This is not a policy *per se*, but really just a statement about a relationship that is implied by the control problem. Target rules still require instrument rules for implementation.

Inferring policy-makers' preferences
Cecchetti and Ehrmann (2001) use this simple model to infer policy-makers' inflation variability aversion. What we do is to estimate α for a broad cross-section of countries. We note that if we assume policy-makers are acting optimally, then their actions reveal their objectives. Given the structure of the economy, summarized by the parameter ω in (5), the observed level of output and inflation variability allow us to estimate the parameter corresponding to α.

The motivation for that study is the set observations in section II. That is, the increase in the number of countries that focus on inflation as a policy objective. One interpretation of a move to inflation targeting is that the preferences of monetary policy-makers have changed, with many central banks exhibiting increasing aversion to inflation variability and decreasing aversion to output variability.

Ehrmann and I estimate the change in the preferences of monetary policy-makers in a cross-section of 23 countries, including nine that target inflation

explicitly. We find evidence that in all countries, whether they target inflation or not, aversion to inflation variability increased during the decade of the 1990s. Furthermore, we show that the inflation targeters increased their aversion to inflation volatility by more than the non-targeters, suggesting that the move to inflation targeting led to some increase in output volatility.[17]

VI. SIMPLE VERSUS COMPLEX RULES AND THE TAYLOR RULE

There is now an extensive literature examining the robustness of simple policy rules. The papers in Taylor (1999*b*) are examples. This research studies the performance of simple rules that react only to inflation and output, and possibly exchange rates, in the context of complex structural models. I will use the framework here to interpret these exercises.

It is helpful to distinguish among several ways in which we can write policy rules. First, there are rules that are written in terms of shocks, as in the case of equation (6) of my example, as compared with those that are written in terms of the observable economic variables. In the latter category we can differentiate between rules specifying reaction to changes in the objectives alone and those that allow for reaction to other things. Yet another distinction is between rules that react only to current variables and those that allow for reactions to past or lagged events.

When dealing with optimal rules, the distinction between those that react to observables and those that react to shocks is actually immaterial. The reason is that any loss-minimizing rule will always specify a set of reactions to new information. That is, the instrument will respond to the shocks. Depending on the dynamic structure of the economy, these responses could be complex, but that will be all there is.

The *Taylor rule*, first introduced in Taylor (1993), is an example of a simple rule that is written in terms of objectives. Taylor suggests that interest rates be

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[17] The methodology used in Cecchetti and Ehrmann (2001) assumes that policy-makers are always on the output–inflation variability frontier, and so their policies are optimal. A recent paper by Cecchetti *et al.* (2000*a*) allows for operation off the frontier, and examines improvements in the efficiency of policy-makers as well as changes in their preferences.

set based on the distance that output and inflation are from their target paths. We can write this as

$$r = \gamma_\pi \pi + \gamma_y y \qquad (9)$$

where γ_π and γ_y are constants.

While there are many models in which the optimal interest-rate response can be written as a Taylor rule, this will not generally be the case. There are a number of reasons why this might be so.

The first reason is that, in some cases, writing the rule in terms of objectives may mean that, for any reasonable parameters, it cannot cause the policy instrument to respond optimally to shocks. The simple example developed in section V is one case in which this is true. To see why, substitute the reduced-form equations (4) and (5) into equation (9). This can be rewritten as

$$r = \frac{(\omega\gamma_\pi + \gamma_y)d + \gamma_\pi s}{1 + \lambda(\omega\gamma_\pi + \gamma_y)}, \qquad (10)$$

which is in the same form as the linear interest-rate rule (6). But it is straightforward to show that, for this particular case, there are no values of γ_π and γ_y such that the coefficients in (10) on d and s equal a^* and b^*. To see this, simply note that the coefficient on d in (10) implies that

$$\omega\gamma_\pi + \gamma_y = \frac{a}{(1 - \lambda a)} \qquad (11)$$

However, we know from the previous section that $a^* = \lambda^{-1}$, which means that the right-hand side of equation (11) is infinitely large, requiring that one or both of γ_π and γ_y must be infinitely large. The optimal rule thus cannot sensibly be expressed in the form of (10).[18]

The second reason is that there is no reason to believe that outcomes for a small set of objectives, here inflation and output, are capable of adequately summarizing the effects of shocks hitting the economy. In particular, in a real-world economy in which both shocks and policy take time to have effect, there may be shocks which are known to

have hit, or be about to hit, the economy, whose effects on output and inflation have not yet been observed. Good policy will want to be pre-emptive in such circumstances, and a simple Taylor rule, in which policy is constrained to respond only to current output and inflation, does not allow this to be done.

Does this mean that it is better for policy-makers to use more complex rules than a simple rule such as that suggested by Taylor? The answer is probably yes. An important relevant case is examined in some detail in Cecchetti *et al*. (2000), who look at the efficacy of reacting to asset prices generally. That study finds that a central bank concerned with most combinations of output and inflation variability (a wide range of αs), can improve performance by modifying its policy rule to include not only inflation and output, but also asset-price misalignments. That is, macroeconomic stability is enhanced if policy responds to the emergence of stock-price and exchange-rate movements. This will be especially true if it appears likely that asset-price movements include the effects of bubbles which are likely to be reversed at a later date.

The lesson of this section is that central banks can almost always improve on simple rules, because the simpler ones are not optimal. There is no reason to believe that information on output and inflation is always capable of adequately summarizing what policy needs to do to respond to the shocks hitting the economy. As a result, judiciously chosen but complex policy rules will almost always be better than simple ones.

VII. MONETARY POLICY-MAKING UNDER UNCERTAINTY

When it was suggested that the European Central Bank (ECB) hold a conference on monetary policy-making under uncertainty, the ECB's Chief Economist, Otmar Issing, responded 'Is there any other kind?'[19] Only in our stylized models is there certainty. Practical advice to central bankers must be

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[18] This is a simple consequence of the insight of Phillips (1954) that a *proportional* feedback-control rule cannot drive the objective of policy to its desired value unless it is infinitely strong.

[19] The conference is summarized in Angeloni *et al*. (2000). That proceedings volume provides a summary of the broad range of issues raised by introducing uncertainty into central bank decision-making.

made in the context of a framework that explicitly considers uncertainty. This has been the subject of a large body of research in recent years. I have already mentioned the work of Sack and Weiland (1999), and now I will elaborate on some of the issues that have been raised.

Uncertainty can be divided into three categories. Using the terminology introduced in section V, there is uncertainty about current economic conditions where the policy-maker cannot observe s and d perfectly, there is uncertainty about the parameters of the model where ω cannot be measured accurately, and there is uncertainty about the model itself where the relationships (2) and (3) may not be correctly specified.

Analysis of the first two of these can proceed in the context of the example. The first result, for which Svensson and Woodford (2000) provide a general proof, is that with a quadratic objective function, optimal policy is unaffected by uncertainty about the state of the economy. Instead, policy-makers should respond in the same way to their best forecast of the shocks as they would if they knew the shocks. This result comes from certainty equivalence, and should not be surprising. In the example, note that the solutions for the optimal responses, a^* and b^*, do not depend on the variances of the demand and supply shocks, and so they will not change if those variances change. From the point of view of the policy-makers, introducing noise into the data is exactly equivalent to increasing the variance of the shocks.[20]

Parameter uncertainty is an entirely different matter. This problem, first examined by Brainard (1967), has now been studied extensively. In its simplest form, Brainard uncertainty reduces the reaction to any shock. That is, if we have an estimate of ω that has a variance σ_ω, then b^* will be negatively related to σ_ω. The bigger the uncertainty about the reaction of output to an interest-rate change, the less sensitive the policy will be to a given size shock. The intuition for this is that the policy-maker will be concerned that the ω may be very small (recall that b^* is inversely related to ω) and not want to take the risk of destabilizing the economy.

More recently, researchers have noted that parameter uncertainty may not always breed caution. Söderström (1999) discusses how, if inflation is very persistent, uncertainty about the effective of policy will cause policy-makers to be more aggressive. The logic is straightforward. Since central banks want to keep inflation low, if a mistake can drive inflation up for a long time, they will want to make sure that does not happen. Uncertainty about the impact of interest-rate changes on inflation will create concern that the policy action might be too timid. Too small an interest-rate move, when inflation is very persistent, results in poor long-term performance. Insuring against this possibility means more aggressive, not more conservative, policy actions.

In the end this is an empirical issue. My own view is that the persistence of the inflation process depends crucially on the monetary policy framework that is in place, and the ability of the central bankers to behave credibly. With a credible, low-inflation policy, inflation will not become persistent in its movements away from the publicly specified target, and so policy-makers can afford to be conservative. The fact that interest-rate changes are smaller than our models predict they should be is at least prima-facie evidence for this position.

Finally, what about model uncertainty? The problems here are quite serious, and the solution taken by the policy-makers is that they are not too tied to the results for any particular model. For economists studying monetary policy, the most useful strategy is that suggested by McCallum (1999), who argues convincingly that since there is little agreement over the true structural economic model, a policy rule should be robust to the possibility that numerous models are correct.[21]

VIII. MAKING MONETARY POLICY IN THE REAL WORLD

Setting interest rates is still more of an art than a science. No one would want to replace central bankers with computers programmed to follow

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[20] Orphanides (2000) notes that, if policy is suboptimal, then data errors have more pernicious effects as they create large policy errors.

[21] Taylor (this issue) provides exactly this type of evaluation of a set of policy rules.

systematic rules based on an optimal control problem of the type I have described—at least, not yet. What is it then, that policy-makers do, and how do they use macroeconomic models and academically generated policy rules?

As Donald Kohn (1999) writes, policy-makers themselves 'seem to regard the use of rules to guide policy as questionable in part because they are quite uncertain about the quantitative specifications of the most basic inputs required by most rules'. Among other things, implementation of specific policy rules usually requires assumptions about the current level of potential output and the equilibrium exchange rate and interest rate. We are unfortunately ill-informed about all of these.

But central bankers do have some use for policy rules. In fact, I am fairly certain that internal central bank documents include estimates of interest-rate levels implied by a broad array of possible rules. These Taylor-style policy reaction functions are estimated using historical data and so they summarize previous policy-makers' decisions in how to move interest rates in reaction to prices, output, and possible exchange-rate movements.

Kohn suggests that by providing this link with the past, estimated rules help provide a benchmark for the stance of policy, giving current policy-makers a sense of how their predecessors (or their former selves) would have reacted under current circumstances. In addition, rules help to structure the massive amount of incoming information. While it is perceived (probably correctly) as dangerous to be dogmatic about rules, it is helpful to think that the proper policy stance is probably affected by the way in which new data affect forecasts about inflation, output, exchange rates, and long-term real interest rates.

Even though central bankers do not follow easily-articulated rules when they adjust their policies, what they actually do is to follow procedures that are *ad-hoc* versions of solving an optimal control problem. As Alan Budd (1998) suggests, policy-makers move interest rates in such a way as to make their forecasts of their inflation and output match up with their targets. That is, they adjust their instrument to make sure that the expected future state of the economy follows along a path that meets their objectives. This means that, implicitly or explicitly, they are using structural models and reaction functions. This is where the study of policy rules comes into play. Central bankers will inevitably set interest rates by reacting to changing economic and financial conditions in order to meet a certain set of objectives. There will always be better or worse ways of doing this, and so the study of policy rules informs these actions, helping to improve the outcomes.

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