Editor's Note

This issue of the *Economic Quarterly* includes the Richmond Fed's 2003 *Annual Report* essay, written by Al Broaddus and Marvin Goodfriend. In this essay, the authors summarize and build on an approach to monetary policy that they have developed over many years working here at the Bank. In particular, they discuss how the knowledge gained through the process of reducing inflation can be applied to the new problem of sustaining price stability. Their approach draws on the new neoclassical synthesis, an analytical framework that emphasizes the decentralized price-setting of monopolistically competitive firms. To further illuminate this framework, this issue of the *Quarterly* reprints Goodfriend's primer on the subject. Also in this issue, Bob Hetzel's interpretation of how the Fed controls inflation is influenced by certain aspects of the new neoclassical synthesis but differs somewhat from that approach, and Yash Mehra examines alternative empirical specifications of a Phillips curve relationship for explaining inflation behavior.

—John A. Weinberg
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Sustaining Price Stability

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The year 2003 was a watershed in Federal Reserve history. In his semiannual testimony to Congress on monetary policy in July, Chairman Greenspan declared that measures of core consumer inflation had decelerated in the first half of the year to a range that could be considered "effective price stability."[1] The Chairman paused briefly to acknowledge, with understated satisfaction, the achievement of this goal, which Congress had assigned to the Federal Reserve and the Fed had pursued for over two decades. He quickly pointed out, however, that the Fed would be confronted now with new challenges in sustaining price stability—specifically preventing deflation as well as inflation. Earlier in the year, at the conclusion of its May meeting, the Federal Open Market Committee (FOMC) had expressed concern for the first time that inflation might decline too far, saying that "the probability of an unwelcome substantial fall in inflation, though minor, exceed(ed) that of a pickup in inflation from its already low level."[2]

The case for maintaining price stability—in the United States and elsewhere—is rooted in experience and theory, which indicate that monetary policy best supports employment, economic growth, and financial stability by making price stability a priority. The full rationale for price stability has been elaborated elsewhere, and we will refrain from repeating it here.[3] This article, instead, is about how to sustain price stability now that it has been achieved. We build our argument in several stages. First, we present a framework for understanding the inflation and deflation processes. Our framework, borrowed from the "new neoclassical synthesis" macroeconomic model, focuses on the management of the markup of price over marginal cost by monopolistically

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[1] See Greenspan (2003, 5).
[2] See Bernanke (2003) for a discussion of the nature of the deflation risk.
[3] See, for instance, Goodfriend and King (2001) and Goodfriend (2004).

competitive firms.[4] Next, we provide examples of shocks that are potentially inflationary or deflationary and explain how interest rate policy actions can counteract them effectively to maintain price stability.

The Fed's current hard-won credibility for low inflation is a foundation of efficient monetary policy because it anchors expected inflation. We review briefly why inflation scares create problems for monetary policy. Addressing the challenge noted by Chairman Greenspan, we explain why deflation scares are equally problematic. Unfortunately, credibility for containing inflation does not necessarily imply credibility against deflation because while there is no upper bound on nominal interest rates to resist inflation, there is a lower bound at zero. We explain how the Fed can use monetary policy—even at the zero bound—to preempt deflation and acquire credibility against deflation to complement its anti-inflation credentials.

Communication has come to play an increasingly important and substantive role in the Fed's conduct of monetary policy because open and effective communication is a crucial ingredient in building and maintaining credibility for price stability. Good communication requires clear long-run policy objectives and clarity in conveying the reasoning behind short-run policy actions aimed at achieving those objectives. In line with our macroeconomic framework, we believe that both purposes would be well served if the Fed publicly announced an explicit long-run inflation target and made more prominent use of price-cost gap, employment gap, and output gap indicators in explaining the stance of monetary policy. In particular, we explain how, in our view, these changes would help minimize the kind of communication problems the Fed faced in 2003 in signaling its concern about deflation and its policy intentions for dealing with the rising risk of deflation at that time.

Having outlined what we want to accomplish in this article, let us emphasize that what follows is our understanding of the issues and our suggestions for dealing with them. Some of our views are shared by our Fed colleagues, others are not. This is no cause for embarrassment. Monetary policy and its effect on the economy is a complex and subtle subject; there is plenty of room for different approaches and divergent views.

1. THE FUNDAMENTAL PRINCIPLE OF PRICE STABILITY

Our approach to thinking about the maintenance of price stability focuses on how monopolistically competitive firms set their prices over time.[5] This

[4] New neoclassical synthesis (NNS) models feature complete microeconomic foundations as in real business cycle economies and imperfect competition and sticky prices as in New Keynesian economies. New synthesis models are thoroughly discussed and analyzed in Goodfriend and King (1997, 2001) and Woodford (2003). The Federal Reserve Board's FRB-US macromodel shares many of the central features of the NNS approach (see Brayton et al. [1997]), as does the model of monetary policy discussed extensively in Clarida, Galí, and Gertler (1999).

[5] Monopolistically competitive firms have the market power to set their product price above the marginal cost of production.

approach is useful because it highlights how monetary policymakers must create an environment within which firms *choose* to maintain stable prices on average.[6]

For our purposes, a key feature of price-setting in practice is its discontinuous character. It is costly for a firm producing a distinctive product to determine the exact price that maximizes its profits at every point in time. Forecasts of demand and cost conditions are expensive to obtain. Moreover, pricing must compete with other claims on management's time, such as production and marketing decisions. Consequently, pricing gets the attention of management only every so often.

For all these reasons, a firm is apt to consider changing its product price only when demand and cost conditions threaten to move its actual markup of price over cost *significantly* and *persistently* away from its profit-maximizing markup.[7] Given a firm's current product price, higher production costs compress its markup, and lower production costs elevate its markup. Production costs, in turn, increase with the hourly wage a firm must pay its workers and decrease as labor productivity (output per hour) rises.[8]

Potential inflation arises when a significant compression of markups is widely expected by firms to persist. In this case, firms raise product prices over time to cover higher expected costs. Potential deflation develops if firms expect significantly elevated markups to persist. Competition for product market share in this latter case induces firms to pass along lower costs via lower prices.

Such reasoning implies the *fundamental principle of price stability*: inflation will remain low and stable if and only if departures from profit-maximizing markups are expected to be relatively small and transitory across firms, so firms are content to raise prices at the existing low inflation rate on average. Note that we consider low and stable inflation to be "effective price stability," in keeping with Chairman Greenspan's characterization.

The historical record shows that in the long run competition among firms for labor pushes real wages (nominal wages adjusted for inflation) up at about the same rate as labor productivity grows. Consequently, real production costs in the aggregate are stable in the long run. Nominal wages, in turn, tend to rise at the rate of productivity growth plus the rate of inflation; therefore, nominal production costs rise at about the rate of inflation in the long run. In the short run, however, shocks to aggregate demand and productivity can cause production costs to vary significantly and persistently relative to prices.

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[6] The term "on average" is important. Obviously, individual firms adjust particular prices in response to sector- and firm-specific demand and supply conditions as well as the broader pricing environment.

[7] An excessively high markup is counterproductive because it yields too much market share to competitors; conversely, a markup that is too small does not exploit a firm's market power sufficiently.

[8] We focus on labor and ignore capital and raw material costs to simplify our exposition. Labor costs alone account for about two-thirds of the cost of producing goods and services.

2. COUNTERACTING SHOCKS TO PRICE STABILITY

This section builds on the fundamental principle of price stability discussed in the previous section to explain how monetary policy, working through short-term interest rates, can counteract inflationary or deflationary shocks to the economy. The argument is straightforward: interest rate policy maintains price stability by managing aggregate demand so as to stabilize the actual markup at the profit-maximizing markup on average across firms.[9] (What follows is tightly reasoned but well worth working through, since it describes the core relationships policymakers must focus on to succeed in maintaining price stability.)

An *in*flationary shock generates a sustained acceleration in production costs, and therefore a compression of the average markup that inclines firms to raise prices above the previously expected low inflation rate *unless* the Fed uses interest rate policy actions to reverse the increase in costs and the markup compression. A *de*flationary shock, in contrast, generates a sustained deceleration or decline in production costs and an increase in the markup that requires offsetting Fed interest rate actions. Exactly how interest rate policy works to stabilize the markup is explained below.

For expositional purposes, it is useful to divide shocks with inflationary or deflationary potential into two categories. We consider first shocks to expected future income prospects. Subsequently, we take up shocks to current productivity growth.

Shocks to Expected Future Income Prospects

Whatever the source of optimism or pessimism about the future, shocks to expected *future* wages and profits are likely to be transmitted to *current* aggregate demand.[10] Households will want to adjust current as well as future consumption to reflect any changes in expected lifetime resources. And firms will want to invest more or less currently in response to any changes in expected future profits.

In these circumstances, *optimism* about future income prospects is potentially *inflationary* because it increases the current demand for labor, raises wages, and compresses markups. On the other hand, *pessimism* about future prospects is potentially *deflationary* because it eases competition in the labor market, slows wage growth, and elevates markups.

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[9] See Goodfriend (2002) for an exposition of the mechanics of interest rate policy geared to maintaining price stability in a new synthesis model. Woodford (2003) presents an extensive treatment of interest rate policy. Clarida, Galí, and Gertler (1999) provide a useful survey. We ignore the zero-bound constraint on interest rate policy in this section, assuming, in effect, that the shocks are small enough that the zero-bound constraint never binds.

[10] Optimism or pessimism regarding job prospects, profitable investment opportunities, taxes, and war, for example, would all affect future income prospects.

The key point for monetary policy is this: one way or another, profit-maximizing markups will be restored. The shock may dissipate before inflationary or deflationary forces build up. If not, then either the Fed must restore profit-maximizing markups promptly with interest rate policy actions, or else firms will attempt to restore these markups by raising or cutting product prices, whichever the case may be. Clearly, it is better that profit-maximizing markups be restored by interest rate policy actions without inflation or deflation.

Bottom line: the Fed can offset a potentially inflationary increase in current demand arising from an increase in expected future income prospects by raising real interest rates to increase the return to saving, raise the cost of borrowing, and induce households and firms to defer spending. Higher real rates preempt inflation by reversing the increased current demand for labor, which reduces the pressure on wages and production costs, and restores profit-maximizing markups. Conversely, by lowering real interest rates, the Fed can lower the return to saving and the cost of borrowing, stimulate spending, and offset a potentially deflationary reduction in aggregate demand. Lower real rates, in turn, preempt deflation by strengthening current labor demand, reversing the downward pressure on wages, and recompressing markups.

The argument above proceeded as if firms were not fully confident that the Fed would act promptly to stabilize production costs that would otherwise be affected by shocks to future income prospects. If firms are confident, then they will meet a temporary increase in demand by working current employees more intensively or by hiring temporary workers, rather than by raising product prices. And firms will lay off labor rather than cut prices if they expect the Fed to stabilize production costs in the face of a shortfall in current demand. Note that the average markup will tend to be compressed temporarily in the first case and elevated temporarily in the second case. We will say more below about why the Fed's "credibility" for price stability is the foundation of efficient monetary policy.

Shocks to Current Productivity Growth

Consider next a sequence of *current* shocks to productivity growth that persists unexpectedly at first, but subsequently comes to be expected to persist. Initially, unanticipated increases in productivity growth are potentially deflationary, and decreases are potentially inflationary. We take the deflationary case; the inflationary case is exactly the reverse.

For a *given* growth rate of wages, accelerated productivity growth lowers production costs *directly*. If, at first, the acceleration is not expected to persist, there is little effect on expected future income and little effect on current aggregate demand. In such circumstances, faster productivity growth also slows production costs *indirectly* by reducing current labor demand and slowing the growth of wages. Two historical examples of these effects are particularly noteworthy. Surprisingly persistent *strong* productivity growth in conjunction with a weak labor market helped lower production costs and produce disinflation in 2003. Conversely, surprisingly persistent *weak* productivity growth helped produce inflation in the 1970s.[11]

The longer a surprising acceleration or deceleration of productivity growth persists, the more likely it will come to be *expected* to persist. If these changes in expectations are sufficiently pronounced, they have the potential to offset and reverse the initial risk to price stability arising from the change in productivity growth. This appears to be what happened in the late 1990s when surprisingly persistent increases in productivity growth apparently came to be expected and were extrapolated far into the future. The brightening future income prospects caused aggregate demand to grow even *faster* than productivity for a time near the end of the decade. Labor markets tightened, real wages grew about as fast as productivity, and inflation remained low and stable. Indeed, there was concern at the time that inflation might *rise* if the increase in demand stimulated by the higher expected future income growth outstripped the restraining effect of the higher productivity growth on prices.

Whether current shocks to productivity are potentially inflationary or deflationary, the Fed can act to offset that potential with interest rate policy. Again, the guiding policy principle is to manage aggregate demand to stabilize production costs so as to sustain profit-maximizing markups on average. The Fed must *reduce* real interest rates to defuse the potential for deflation when a period of faster productivity growth is not expected to persist. In this situation, lower real interest rates must stimulate aggregate demand sufficiently to offset the weakness in labor markets and thereby allow wage increases to reflect the higher productivity. Alternatively, if the public comes to regard a period of faster productivity growth as an increase in *trend* growth, then the Fed might have to *increase* real interest rates to relieve the potential for *inflation*. Specifically, interest rates would have to rise enough to limit the increase in current aggregate demand to what can be satisfied by the *current* increase in productivity at the profit-maximizing markup.

Having outlined these policy prescriptions, we want to be quick to acknowledge—as practical policymakers—that implementing them with consistent success is far from rote. Measuring and predicting the relevant aggregate variables is difficult enough; estimating and tracking indicators of the average profit-maximizing markup is even more so. Modeling the transmission of interest rate policy actions to demand, production costs, and inflation requires sophisticated econometric techniques. And discerning whether the public *perceives* an increase in productivity growth as transitory or more lasting, for

[11] Weak productivity growth, however, was only part of the story in the 1970s: inflation rose long before the extended productivity slowdown began in 1974 and fell briefly thereafter, before rising again in 1978.

example, is not easy. Tasks like these are as challenging as they are crucial. Some would refer to the judgments involved in this work as the "art" of monetary policy.

3. THE IMPORTANCE OF CREDIBILITY FOR STABLE PRICES

As the foregoing has already suggested, *credibility* is an essential component of effective monetary policy. The long campaign from the late 1970s through the early 1990s to reduce inflation and establish price stability arguably succeeded only when the Fed finally acquired credibility for low inflation in the eyes of the public in the late 1990s. Indeed, the acquisition of this credibility was essentially equivalent to establishing price stability—two ways to describe the same achievement. Similarly, the Fed needs to acquire credibility for *sustaining* price stability going forward.

The previous section showed how interest rate policy actions can counteract inflationary or deflationary shocks and perpetuate credibility presuming that it has already been established. In this section we explain why full credibility for maintaining price stability is so useful, and how its absence can cause serious problems.

Credibility for stable prices produces three critically important benefits. First, credibility *anchors* inflation expectations so that nominal federal funds rate target changes translate clearly into real interest rate changes, which helps the Fed gauge the likely impact of its policy actions on the economy. Second, credibility *buys time* for the Fed to recognize and counteract threats to price stability. Third, credibility *enhances the flexibility* of interest rate policy to respond aggressively to transitory shocks that threaten to destabilize financial markets and create unemployment.

The absence of credibility, on the other hand, creates problems for monetary policy. The history of post-World War II monetary policy in the United States features numerous *inflation scares* marked by sharply rising long-term bond rates reflecting increased expected inflation premia.[12] Inflation scares create a fundamental dilemma for monetary policy. At the initial nominal federal funds rate target, higher expected inflation lowers the *real* federal funds rate and intensifies the inflation scare by stimulating current aggregate demand and compressing the markup. In these circumstances, the Fed could raise its *nominal* federal funds rate target just enough to leave the real rate unchanged; but that would do nothing to reverse the collapse of confidence.

Inflation scares are dangerous because ignoring them encourages even more doubt about the Fed's commitment to low inflation. And restoring credibility for low inflation requires the Fed to weaken labor markets deliberately

[12] See Goodfriend (1993). See Orphanides and Williams (2004) for a quantitative, theoretical analysis of inflation scares in a model of perpetual learning.

with higher real interest rates in order to slow wage growth, elevate markups, and induce firms not to raise prices—rarely a popular policy stance with the public or the political establishment. It is in large part to avoid the risk of recession posed by inflation scares that the Fed has learned to preempt inflation with interest rate policy.

Unfortunately—and this is a crucial point in appreciating fully the policy implications of the transition from fighting for price stability to maintaining it—credibility for controlling inflation does not automatically translate into credibility for preventing deflation. A *deflation scare* obviously does not confront the Fed with a choice between contracting employment and loosing credibility. On the contrary, the way to resist a deflation scare is to reduce real interest rates in order to stimulate demand, tighten labor markets, raise wages, and compress the markup. The problem is that given the zero bound on the nominal federal funds rate, interest rate policy alone might have insufficient leeway to deter deflation, especially since the federal funds rate is low on average when expected inflation is low. Moreover, the Fed would have to drive the nominal federal funds rate ever closer to zero to prevent disinflationary expectations from raising the real federal funds rate. And deflation expectations would actually *raise* the real federal funds rate at the zero bound and exacerbate the deflation scare.

In addition, a policy vacuum at the zero bound could encourage ill-advised fiscal actions. Some fiscal actions would be desirable as we explain below; but many would not be. For instance, the government might enact legislation that results in wasteful government spending, inefficient credit subsidies, or forbearance in the banking system related to deposit insurance. The government might also resort to off-budget policies such as anti-competitive measures to support wages or prices in particular sectors. All told, such fiscal actions could lower potential GDP substantially.[13] In doing so, they would lower future income prospects, lower current aggregate demand, contract current employment, lower wages and production costs, and exacerbate the deflation problem. This appears to be what happened in the Great Depression of the 1930s.[14]

Ultimately then, a deflation scare, like an inflation scare, is problematic because it has the potential to lead to a protracted recession. From this perspective, even those who care mainly about employment and output can understand why the Fed must establish credibility as a deflation fighter as well as an inflation fighter by making price stability a priority and resisting deviations from it in either direction.

[13] Potential GDP refers to the path of output consistent with the maintenance of price stability.

[14] Kennedy (1999) describes U.S. economic policies in the 1930s as a collection of market interventions taken to support favored sectors of the economy. Cole and Ohanian (2001) model these interventions and show quantitatively that they can explain the persistence of the Great Depression in the United States.

Moreover, credibility against inflation and credibility against deflation are mutually supportive: each strengthens the other, and each is weaker without the other.[15] As we pointed out above with respect to inflation scares, policy must compensate for insufficient credibility in one direction by taking risks in the other direction. We make this point again as it pertains to establishing credibility against deflation.

4. DEFEATING DEFLATION AT THE ZERO BOUND

But how can the Fed establish credibility for preventing deflation given the zero bound on the nominal funds rate? In brief, the Fed should make arrangements to overcome operational and institutional obstacles identified below that could impede the effectiveness of monetary policy at the zero bound. The publication of a contingency plan for the aggressive pursuit of monetary policy against deflation at the zero bound would greatly reduce the likelihood and force of deflation scares and help guarantee that the devastating effects of deflation experienced earlier in U.S. history will not be repeated.[16]

But how, specifically, can the Fed confront a deflationary risk when the funds rate is at the zero bound? Most importantly in our view, the Fed can continue to inject money into the economy by buying assets and expanding its balance sheet when conventional interest rate policy is immobilized at the zero bound.[17] Some economists believe that expanding the monetary base would stimulate spending directly through a monetarist channel of monetary transmission. Others focus on how Fed purchases of long-term bonds would stimulate spending by lowering long-term interest rates. Still others believe that expanding the balance sheet would work by creating expectations of inflation that would push real interest rates below zero if the Fed held the nominal federal funds rate at zero.

Even though we do not know the relative strength of these three transmission channels, and others that may exist, we do know this: monetary policy must be able to defeat deflation at the zero bound; otherwise, the government could eliminate explicit taxes and finance all of its expenditure forever with money created by the Fed![18] The challenge is to identify and overcome opera-

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[15] It is worth pointing out that credibility for price stability is also threatened when Fed participation in foreign exchange operations with the Treasury creates doubt about whether monetary policy will support domestic or international objectives. See Broaddus and Goodfriend (1996).

[16] Deflations in the early 1920s and in the 1930s were particularly destructive; milder deflations at other times caused less distress.

[17] The Fed is not free to expand the size of its balance sheet as long as it targets a federal funds rate even slightly above zero. In that case, the size of its balance sheet is constrained to create a scarcity of bank reserves just sufficient to maintain the desired positive federal funds rate.

[18] Technically, a deflation trap is not a possible rational-expectations equilibrium if the nominal value of total government liabilities will not decline, even in the presence of sustained deflation. See Woodford (2003, 133).

tional and institutional obstacles to the credible implementation of quantitative monetary policy as opposed to interest rate policy, where "quantitative monetary policy" refers to open market purchases that expand the volume of assets and monetary liabilities on the Fed's balance sheet.

What are these operational and institutional obstacles? One problem is that the bang for the buck of quantitative monetary policy at the zero bound is unknown and may be relatively weak. It follows that the Fed must be prepared, if necessary, to *overshoot* temporarily the long-term, steady state size of its balance sheet by a wide margin. But to do so, the Fed must have a credible *exit strategy* for draining whatever monetary base threatens excessive inflation *after* it has successfully concluded its deflation-fighting policy actions.

A second problem is that short-term government securities are perfect substitutes for the monetary base at the zero bound; therefore, the Fed would have to buy longer-term government securities, private assets, or foreign assets for quantitative policy to be effective at the zero bound.[19] The current outstanding *stock* of longer-term government securities together with the prospective *flow* of future government borrowing may very well provide sufficient government securities for the Fed to buy—that is, monetize—to defeat deflation at the zero bound.

To lock in credibility against deflation, however, the Fed will need more fiscal support for quantitative policy at the zero bound than it is usually granted by the fiscal authorities, i.e., Congress and the Treasury. For example, in some circumstances, there might not be enough outstanding longer-term government bonds to purchase, or government budget deficits to monetize, to make the quantitative policy effective. Of course, the Fed could buy other assets. But buying domestic private assets or foreign assets on the large scale contemplated here would create other credibility problems.[20] Additionally, this strategy would expose the Fed to capital losses that might leave it with insufficient assets to reverse a huge expansion of its balance sheet, should that be required.[21]

The fiscal authorities could enter the process in a number of ways. In particular, they could support the Fed's exit strategy by committing to transfer enough government securities to the Fed—in effect to recapitalize the Fed if necessary—to allow the Fed to drain whatever base money needed to be withdrawn from the economy following an aggressive anti-deflation action by the Fed at the zero bound. In addition, the fiscal authorities could agree to run a budget deficit to help inject money into the economy. The Fed could monetize

[19] When the federal funds rate has been pushed to zero, there is no opportunity cost to holding currency or bank reserves relative to short-term securities. Hence, the public is indifferent at the margin between holding cash or short-term securities, and open market purchases of short-term securities have no effect.

[20] See Broaddus and Goodfriend (2001).

[21] For instance, long-term bonds purchased to stimulate the economy when interest rates are near zero suffer large capital losses when interest rates rise as the economy recovers.

short-term debt issued to finance the deficit and then withdraw excess base money later by selling the debt back to the public. In this way, monetary policy could be made *completely credible* against deflation in virtually any situation.

This discussion may strike some readers as far-fetched. But while the probability is low that a deflationary threat of the magnitude contemplated here at the zero bound will emerge in the future, if it did, the consequences of not being fully prepared to deal with it could be exceptionally damaging to the economy. Consequently, we believe it is essential to have contingency arrangements of the kind we have just described firmly in place in advance.

5. IMPROVING COMMUNICATION IN SUPPORT OF PRICE STABILITY

Up to this point, we have explained the economics of maintaining price stability in the context of a modern macroeconomic model, and indicated the critical importance of credibility in this effort, including credibility for confronting the risk of deflation at the zero bound. This last section of our article addresses a final element in the strategy for maintaining price stability: clear communication with the public regarding both the strategy itself and short-term actions taken in the defense of price stability.[22]

The macroeconomic model of the inflation and deflation processes outlined above suggests two substantial opportunities for the Fed to improve its communication practices in ways that would strengthen its strategy for maintaining price stability. First, the Fed can lock in long-run price stability and clarify its short-run concerns and policy intentions regarding inflation by publicly announcing an explicit low long-run inflation target. Second, the Fed can clarify its reasons for taking particular short-run policy actions to preempt potential inflation or deflation by talking in terms of the average gap between the actual markup and the profit-maximizing markup, and closely related indicators of labor market tightness, which we identified earlier as the proximate determinants of price pressures. Our arguments for these two recommendations are developed below.

Clarifying Short-Run Policy Aims with an Inflation Target

Although the Fed has made price stability a priority for monetary policy, it does not publicly and explicitly specify a target range for inflation. Instead, the Fed signals its concerns about inflation or deflation in its post-FOMC meeting statements and minutes, and in the Chairman's monetary policy reports to

[22] See Dudley (2003).

Congress. We believe that the Fed's experience in the May–June 2003 period indicates that references to inflationary or deflationary risks cannot reliably substitute for an explicit long-run inflation target.

The indication in the announcement following the May 2003 FOMC meeting that significant further disinflation would be unwelcome, in our view, effectively put a lower bound on the Fed's tolerance range or comfort zone for inflation. At the time, inflation was running at around 1 percent in terms of the core PCE, one of the Fed's preferred inflation measures.[23] The assertion of a lower bound seemed prudent given the deflation risk discussed above and the fact that the federal funds rate at the time was 1 1/4 percent. The Fed's statement served two useful purposes—it alerted the public to the small but real risk of deflation while also asserting implicitly that the Fed would act to deter further disinflation.

The assertion of the lower bound on inflation, however, came as a surprise that took the expected future path of the federal funds rate sharply lower and pulled longer-term interest rates down as well. Commentary in the media amplified nervousness about deflation well beyond what was justified in the economic data. In the event, the Fed reduced its federal funds rate target only 25 basis points, rather than the widely anticipated 50 basis points, at the June FOMC meeting. And longer-term interest rates promptly reversed field.[24]

Our reading of this episode is that references to the probability of rising or falling inflation in FOMC policy statements cannot reliably substitute for an announced, explicit inflation target range. One of the most important lessons of rational expectations theory is that it is particularly difficult for the public to gauge the intent of a policy action taken out of context, and, therefore, it is particularly difficult for the Fed to predict the effect of an unsystematic policy action.[25] We think this reasoning extends to policy announcements as well. Since the ad hoc implicit announcement of a lower bound on the Fed's tolerance range for inflation was unsystematic by definition, it is not surprising that the announcement caused confusion, nor that the Fed failed to predict the public's reaction. In this case the reaction was excessive, but in another situation there might have been an insufficient reaction.

If an inflation target range had been in place in 2003, the public could have inferred the Fed's growing concern about disinflation as the inflation rate drifted down toward the bottom of the range through the first half of the year. Expected future federal funds rates and longer-term interest rates would have moved lower continuously, with less chance of overshooting or undershooting the Fed's intended policy stance. We recommend that the Fed publicly commit to maintaining core PCE inflation within a target range of 1 to 2 percent over

[23] See Federal Open Market Committee (1996, 11).
[24] See Ip (2003, June 27 and August 15).
[25] McCallum (2004) makes a related point.

the long run so that such misunderstandings won't recur at *either* end of the Fed's tolerance range for inflation.[26]

The Fed's assertion of an inflation target might appear to some to usurp a congressional prerogative. We think otherwise for three reasons.

First, we believe a compelling case can be made that, beyond underlining the Fed's long-term responsibilities for price stability, an inflation target would be a valuable addition to the Fed's *operational* communications procedures. From this perspective, we believe that at least implicitly Congress has already delegated authority to set an inflation target to the Fed as part of its operational independence.

Second, as we emphasized earlier, monetary policy best facilitates achievement of the Fed's other mandated policy goals—such as maximum sustainable employment, economic growth, and financial stability—by making price stability a priority.

Third, an inflation target would not prevent or hinder the Fed from taking the kinds of policy actions it takes today to stabilize employment and output in the short run. What it would do is discipline the Fed to ensure that these actions are consistent with its commitment to protect the purchasing power of the currency.[27]

Clarifying Short-Run Policy Aims with Gap Indicators

The second opportunity for improved communication noted above is more effective explanation of the reasons for particular short-term policy actions. The macroeconomic framework presented above locates the potential for departures from price stability in the sign, size, and expected persistence of the average *price-cost gap* between actual markups and the respective profit-maximizing markups. In practice, indicators of the *employment gap* and the *output gap* are also used, in conjunction with preferable but hard-to-measure price-cost gap indicators, to assess the risks to price stability.[28] (Recall that tightness or slack in the labor market is what causes nominal wages to accelerate or decelerate. Markup dynamics then govern the transmission of these nominal wage dynamics to the price level.) Recently, the Fed has mentioned

[26] While the core PCE, the Fed's preferred inflation measure internally, seems a straightforward choice for the index on which to base its target measure, the better-known consumer price index could be used instead. Our framework suggests that the Fed should target a core inflation index that closely reflects sticky prices set by monopolistically competitive firms.

[27] This repeats a point made by Broaddus at the January 1995 FOMC meeting. See Federal Open Market Committee (1995, 41).

[28] The output gap measures aggregate output relative to an estimated potential level of output consistent with price stability. The employment gap measures aggregate employment relative to an estimated level of employment believed to be consistent with price stability.

only the *growth* of output or productivity, and the *improvement* or *deterioration* in employment in its policy statements, and has rarely if ever mentioned markups, price-cost gaps, or employment and output gaps.

We recognize that gap indicators are particularly difficult to estimate, especially in real time. One must *measure* the average markup, aggregate employment and output and *estimate* the time-varying levels of these aggregates believed to be consistent with price stability. And one must *forecast* future changes in these gap indicators in order to assess the risks to price stability. Furthermore, one must decide how to weight the various indicators in the overall assessment when inevitable inconsistencies occur.

There is a natural reluctance to feature gaps in the Fed's policy statements because of the unfortunate experience in the 1960s and '70s, when calling attention to employment and output gaps created pressure that ultimately led to inflationary monetary policy and very poor macroeconomic performance.[29] Even so, Fed economists necessarily employ, internally at least, implicit estimates of the price-cost gap, the employment gap, and the output gap to evaluate the potential for inflation or deflation. Therefore, gaps ought to be mentioned more prominently in the Fed's post-FOMC policy statements and other important regular policy reports such as the FOMC meeting minutes and the semiannual monetary policy reports to Congress.[30] This would help to avoid confusion in periods such as the recent past when productivity growth has been rising and fluctuating widely with substantial effects on employment and production costs.

In the second half of 2003 the Fed had difficulty convincing financial markets of its inclination to maintain a low federal funds rate for a "considerable period."[31] One reason for this, in our view, was that its policy statements emphasized explicitly strong real economic growth during the period but paid insufficient attention to the sizable gap in employment and the cumulative deflation in unit labor costs that had almost certainly widened the price-cost gap. The apparent size and likely persistence of these gaps produced the disinflation that occurred in 2003 and constituted the deflation risk that inclined the Fed to keep the federal funds rate low.

To sum up, we believe that the Fed has much to gain and little to lose by referring to price-cost, employment, and output gaps more prominently.[32] By communicating more explicitly in terms of gap indicators, the Fed could clarify

[29] See, for example, Orphanides (2002).

[30] McCallum (2001) discusses conceptual and operational problems involved in measuring employment gaps and output gaps, and argues that monetary policy should not respond strongly to such gaps in its monetary policy rule.

[31] These words were employed initially in the policy statement following the August 2003 FOMC meeting. See Ip (2003, August 13). The FOMC dropped the "considerable period" language at its January 2004 meeting, saying instead that it could be "patient" in raising interest rates.

[32] Our recommendation is consistent with evidence presented in Kohn and Sack (2003) that greater clarity in the Fed's statements about the economic outlook would improve monetary policy.

substantially its views regarding inflationary or deflationary risks and make expected future federal funds rates conform more closely to its preemptive policy intentions.

If the Fed clarifies its short-run policy aims with gap indicators, however, it is critical that it also discipline itself by announcing an explicit long-run inflation target to deal with any inconsistencies that may appear between gap indicators and inflation performance. The Fed should acknowledge its definition of price stability to avoid repeating either the inflationary mistakes of the 1960s and '70s or the deflationary mistakes of the 1930s.

6. SUMMARY AND CONCLUSION

In this article, we have sought to provide a framework for thinking about how monetary policy can maintain price stability. The core principle—taken from the new neoclassical synthesis—is that inflation will remain low and stable if and only if firms, on average across the economy, expect departures from their profit-maximizing markups to be relatively small and transitory. We explained how interest rate policy works to maintain price stability by managing aggregate demand to offset the effect on production costs of shocks to expected future income prospects and current productivity.

Monetary policy is most effective when the public is confident that the Fed will act to stabilize production costs promptly after a shock—what we referred to as "credibility" for price stability. When the Fed has credibility, prices are relatively insensitive to cost shocks on average, since firms expect the Fed to manage aggregate demand to reverse pressures on costs in either direction promptly. Credibility anchors expected inflation and enables the Fed to act aggressively to prevent recessions. On the other hand, we indicated how the absence of credibility raises the risk of recession whenever the economy is confronted with either an inflation scare or a deflation scare.

The Fed's current credibility as an inflation fighter is now firmly established, but the zero bound on interest rate policy impedes the extension of that credibility, in any straightforward way, to deflation. We pointed out, however, that ultimately monetary policy must be able to deter deflation at the zero bound; otherwise, the government could eliminate explicit taxes and finance all of its expenditure forever with money created by the Fed.

We identified several operational and institutional obstacles that the Fed should address to make quantitative policy (as opposed to interest rate policy) credible against deflation at the zero bound. In particular, we pointed out that in order to secure full credibility against deflation, the Fed will need more fiscal support for quantitative policy at the zero bound than is usually granted by the fiscal authorities.

Finally, we offered two recommendations for improving the Fed's communication policy designed to address the kinds of problems the Fed faced in conveying its concerns about deflation in 2003. First, the Fed should commit publicly to maintaining core PCE inflation within a target range of 1 to 2 percent over the long run. We think that an inflation target should be regarded, not just as a policy goal, but as an essential part of communication policy.

Second, the sign, size, and expected persistence of price-cost, output, and employment gap indicators play a central role in gauging the risks to price stability and in preempting inflation and deflation. We recommend that the Fed feature such gap indicators more prominently in its statements and discussions about policy to clarify the potential for inflation or deflation in its outlook, and to clarify its intentions for dealing with these threats. We emphasize that the Fed should announce an explicit inflation target so that it does not stray from price stability under any circumstances.

The role of monetary policy in halting what seemed to be an inexorable rise in inflation in the 1970s, and subsequently reducing it during the ’80s and ’90s to an acceptable level, is in our view one of the greatest achievements in the Fed’s history. We hope that our article will help the Fed to surmount its next challenge—the maintenance of price stability—in the years ahead.

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Monetary Policy in the New Neoclassical Synthesis: A Primer

Marvin Goodfriend

Great progress was made in the theory of monetary policy in the last quarter century. Theory advanced on both the classical and the Keynesian sides. New classical economists emphasized the importance of intertemporal optimization and rational expectations.[1] Real business cycle (RBC) theorists explored the role of productivity shocks in models where monetary policy has relatively little effect on employment and output.[2] Keynesian economists emphasized the role of monopolistic competition, markups, and costly price adjustment in models where monetary policy is central to macroeconomic fluctuations.[3] The new neoclassical synthesis (NNS) incorporates elements from both the classical and the Keynesian perspectives into a single framework.[4] This "primer" provides an introduction to the benchmark NNS macromodel and its recommendations for monetary policy.

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[1] Lucas (1981) and Ljungqvist and Sargent (2000).

[2] Prescott (1986) and Plosser (1989).

[3] Mankiw and Romer (1991), Mankiw (1990), and Romer (1993).

[4] This primer draws on ideas developed in Goodfriend and King (1997, 2001). See also Brayton, Levin, Tryon, and Williams (1997), Clarida, Gali, and Gertler (1999), and Woodford (2003).

The article begins in Section 1 by presenting a monopolistically competitive core RBC model with perfectly flexible prices. The RBC core emphasizes the role of expected future income prospects, the real wage, and the real interest rate for household consumption and labor supply. And it emphasizes the role of productivity shocks in determining output, the real wage, and the real interest rate.

The NNS model introduced in Section 2 takes costly price adjustment into account within the RBC core. In the NNS model, firms do not adjust their prices flexibly to maintain a constant profit maximizing markup. Instead, firms let the markup fluctuate in response to demand and cost shocks. Markup variability plays a dual role in the new neoclassical synthesis. As a guide to pricing decisions, the markup is central to the evolution of inflation. As a "tax" on production and sales, the markup is central to fluctuations in employment and output.

Section 3 locates the transmission of interest rate policy to employment and inflation in its leverage over the markup. That leverage creates the fundamental credibility problem of monetary policy: the temptation to increase employment by compressing the markup jeopardizes the central bank's credibility for low inflation. The nature of the credibility problem is discussed in Section 3 together with the closely related "inflation scare" problem that confronts monetary policy in practice.

Section 4 traces the effects on employment and inflation of three types of disturbances: optimism or pessimism about future income prospects, a temporary productivity shock, and a shift in trend productivity growth. It then tells how interest rate policy can counteract such shocks. The combination of rational forward-looking price setting by firms, monopolistic competition, and RBC components in the benchmark NNS model provides considerable guidance for interest rate policy. The recommended objectives and operational guidance are developed and presented in Section 5. Section 6 addresses three challenges to these policy recommendations. Section 7 is a summary and conclusion.

1. THE CORE REAL BUSINESS CYCLE MODEL

The core monopolistically competitive real business cycle model is presented in four subsections below: First, the representative household's optimal lifetime consumption plan is derived, given its lifetime income prospects and the real rate of interest. Second, household labor supply is derived. Third, employment and income are determined, taking account of the representative household's choice of labor supply, firm profit maximization, and the economy's production technology. Fourth, the real interest rate is determined, emphasizing its role in clearing the economy-wide credit market and in coordinating aggregate demand and supply.

Household Consumption[5]

The economy is populated by households that live for two periods, the present and the future.[6] Households have lifetime income prospects (y_1, y_2) and access to a credit market where they can borrow and lend at a real rate of interest r. A household chooses its lifetime consumption plan (c_1, c_2) given its income prospects and the real rate of interest to maximize lifetime utility subject to its lifetime budget constraint

$$c_2 = -(1+r)c_1 + (1+r)x \tag{1}$$

where $x = y_1 + \frac{y_2}{1+r}$ is the present (period 1) discounted value of lifetime income prospects.

A household obtains utility from lifetime consumption according to

$$U(c_1, c_2) = u(c_1) + \frac{1}{1+\rho}u(c_2) \tag{2}$$

where $u(c_1)$ is utility from consumption in the present, $u(c_2)$ is utility from future consumption, $U(c_1, c_2)$ is the present discounted value of lifetime utility from consumption, and $\rho > 0$ is a constant psychological rate of time discount. For concreteness we work with log utility: $u(c) = \log$ c, so that $u'(c) = 1/c$.

To maximize lifetime utility the household chooses its lifetime consumption plan (c_1, c_2) so that

$$(1+r) = (1+\rho)\frac{c_2}{c_1} \tag{3}$$

where the household's choices for $c_1$and c_2 exhaust its lifetime budget constraint (1).[7] Below we see how lifetime income prospects are determined and how the real interest rate adjusts to reconcile desired aggregate household consumption with aggregate output.

Household Labor Supply

The representative household must also choose how to allocate its time to work and leisure. In deciding how much to work, a household takes the real hourly wage in terms of consumption goods w as given in the labor market.

5 Fisher (1930) and Friedman (1957) pioneered the theory of household consumption.

6 As will become clear below, it is not necessary to specify the length of the two periods in order to explain the mechanics of the forward-looking benchmark NNS model and its implications for monetary policy. The features of the NNS model highlighted here are qualitatively consistent with those of a fully dynamic version of the model specified as a system of difference equations connecting periods of relatively short duration.

7 To maximize lifetime utility, a household must choose c_1 and c_2 so that what it requires in future consumption to forgo one more unit of current consumption, $(1+\rho)\frac{c_2}{c_1}$, equals the interest rate, $1+r$, at which it can transform a unit of current consumption into future consumption by lending.

The household has a time budget constraint

$$l + n = 1 \tag{4}$$

where l is time allocated to leisure, n is time allocated to work, and the amount of time per period is normalized to 1. A household gets utility directly from leisure. Leisure taken in the present and the future contributes to lifetime utility as does consumption. Again we work with log utility so that utility from leisure is given by $v(l) = \log l$ and $v'(l) = 1/l$.

The allocation of time in a given period that maximizes the household's utility is the one for which the marginal utility earned directly by taking leisure equals the marginal utility earned indirectly by working

$$1/l = w/c. \tag{5}$$

Using time constraint (4) to eliminate leisure l in (5) we can express the household's willingness to supply labor n^s as a function of household consumption c and the real wage w

$$n^s = 1 - \frac{c}{w}. \tag{6}$$

Household labor supply (6) has three important features. First, holding the wage w constant, household labor supply is inversely related to household consumption. This makes sense because if the household is able to consume more goods, say, because its lifetime income prospects have improved, then it will wish to consume more leisure as well. Second, holding consumption fixed, labor supply varies directly with the real wage. This also makes sense because, other things the same, a higher hourly wage increases the opportunity cost of leisure and makes work more attractive. Third, if both consumption and the real wage rise equiproportionally, then the effects on labor supply are exactly offsetting. We see below that this last feature of labor supply is important to account for some aspects of long-run economic growth.

Firms, Employment, and Output

There are a large number of firms in the economy, each producing a different variety of consumption goods. Because their products are somewhat different, firms are monopolistically competitive. Each firm has enough pricing power in the market for its own output that it can sustain a price somewhat above the marginal cost of production. Firms face a constant elastic demand for their products, which means that the profit maximizing markup of price over marginal cost is a constant $\mu^* > 1$, invariant to shifts in demand or in the cost of production.[8] For the remainder of Section 1, we assume that firms adjust their prices flexibly to maintain the constant profit maximizing markup μ^* at

[8] This point can be verified with a little algebra.

all times. The demand for all varieties of goods is symmetric, so consumption is treated as a single composite good.

Firms produce consumption goods c from labor input n according to the production technology

$$c = a \cdot n \tag{7}$$

where a is labor productivity per hour in units of consumption goods. Productivity a fluctuates and grows over time with technological progress.

The markup of price over the marginal cost of production is defined as

$$\mu = \frac{P}{MC} \tag{8}$$

where P is the dollar price of a unit of consumption goods, and MC is the cost in dollars of producing a unit of consumption goods. According to production technology (7), $1/a$ hours of work is needed to produce a unit of c. If the hourly wage is W dollars, then the marginal cost in dollars (unit labor cost) of producing a unit of consumption goods is W/a. Substituting for MC in the definition of the markup and rearranging yields

$$\mu = \frac{a}{W/P} = \frac{a}{w} \tag{9}$$

where w is the real wage.

Note that (9) uses only the production technology and the definition of the markup to express the markup μ in terms of productivity a and the real wage w. We see immediately from (9) that the equilibrium real wage w^* is determined as

$$w^* = a/\mu^*. \tag{10}$$

If firms adjust their product prices to maintain markup constancy, the real wage grows and fluctuates only with productivity a. Since the profit maximizing markup exceeds unity, $\mu^* > 1$, the real wage is less than labor productivity $w^* < a$. Firms are content to stop hiring before bidding the real wage up to the marginal product of labor because they maximize monopoly profit by restricting their own output somewhat.

To determine equilibrium employment n^*, use (7) and (10) to substitute for c and w in labor supply function (6)

$$n^s = 1 - \frac{a \cdot n}{a/\mu^*} \tag{11}$$

and equate desired labor supply n^s to labor utilized by firms n to find equilibrium employment n^*

$$n^* = \frac{1}{1 + \mu^*}. \tag{12}$$

Notice that equilibrium employment n^* depends only on the profit maximizing markup μ^* and not on productivity a. The reason is that productivity a affects consumption c and the real wage w proportionally given hours worked n, so that the productivity effects operating through consumption and the real wage in labor supply function (6) are exactly offsetting. This feature of the core RBC model is necessary to account for some fundamental facts about long-run economic growth. For instance, labor productivity in the U.S. economy has grown by more than 2 percent per year for over 100 years; and output and the real wage have both grown at roughly the same rate. Yet the fraction of time allocated to work has changed relatively little during that same period.[9]

Equilibrium output c^* is determined from production technology (7) and equilibrium employment (12) as

$$c^* = a \cdot \frac{1}{1+\mu^*} \tag{13}$$

where output c^* grows and fluctuates proportionally with productivity a.

The Real Interest Rate: Coordinating Demand with Supply[10]

To complete our understanding of the core RBC model, we must check that households have sufficient income to purchase all the consumption goods that firms produce each period *and* that households can be induced to choose a lifetime consumption plan that matches the current and future production of consumption goods. The real interest rate plays the central role in aligning the demand and supply of consumption goods over time.

Households have two sources of income. First, there is wage income which equals the real wage multiplied by hours worked, wn. Second, there is profit income which equals firms' revenue from sales minus the wage bill, $an - wn$. Profits are positive because $w < a$. Since households own the firms, total household income each period is the sum of wage income and profit income $wn + (an - wn) = an$, which is exactly the value of consumption goods produced and sold each period. Thus, households do indeed earn enough income each period to buy the goods produced in each period. It follows that the lifetime consumption plan (c_1, c_2) that matches the current and future supply of consumption goods given by (13), $c_1^* = a_1 \cdot \frac{1}{1+\mu^*}$ and $c_2^* = a_2 \cdot \frac{1}{1+\mu^*}$, also satisfies the lifetime budget constraint (1).

The real interest rate r^* that makes desired lifetime consumption match the intertemporal supply of consumption goods is found by substituting the

[9] Romer (1989).
[10] Fisher (1930).

current and future supply of consumption goods (c_1^*, c_2^*) into condition (3)

$$(1 + r^*) = (1 + \rho)\frac{a_2 \cdot \frac{1}{1+\mu^*}}{a_1 \cdot \frac{1}{1+\mu^*}} = (1 + \rho)\frac{a_2}{a_1} \tag{14}$$

where we see that the equilibrium real interest rate r^* varies directly with the growth of labor productivity, $\frac{a_2}{a_1}$.

One can understand the determination of the real interest rate as follows: When productivity is stagnant $(a_1 = a_2)$, households are satisfied with a flat lifetime consumption plan as long as the real interest rate equals the psychological rate of time preference $(r^* = \rho)$. In that case, the return to lending exactly offsets the preference for consuming in the present. On the other hand, if future productivity is expected to be higher than current productivity $(a_1 < a_2)$, then households want to borrow against their brighter future income prospects to bring some consumption forward in time. In the aggregate, however, households cannot do so because the future productivity has not yet arrived. As households try to borrow against the future, they drive the real interest rate up to the point where they are satisfied with the steeply sloped consumption plan that matches the growth of productivity. The equilibrium real interest rate clears the economy-wide credit market by making the representative household neither a borrower nor a lender. In so doing, the equilibrium real interest rate also clears the economy-wide goods market by inducing the representative household to spend its current income exactly.

2. THE NEW NEOCLASSICAL SYNTHESIS

The new neoclassical synthesis (NNS) builds on the core real business cycle (RBC) model to provide an understanding of fluctuations in employment and inflation and a framework for thinking about monetary policy. The main departure is that firms do not adjust their product prices flexibly in the NNS model to maintain a constant profit maximizing markup. Consequently, the markup fluctuates in response to shocks to aggregate demand and productivity. The remainder of Section 2 explains why markup variability is central to fluctuations in inflation and employment in the benchmark NNS model. Section 3 discusses how monetary policy exerts its leverage over employment and inflation through the markup. Section 4 considers various shocks in the NNS model and explains how interest rate policy actions can counteract them. The recommendations for monetary policy implied by the benchmark NNS model are spelled out in Section 5.

Firm Pricing Practices, Inflation, and the Markup

It is costly for a firm producing a differentiated product to determine the price that maximizes its profits at each point in time. Pricing requires information on a firm's own demand and cost conditions that is costly to obtain. Moreover, that information needs to be assessed and processed collectively by top management. Management must prioritize pricing decisions relative to other pressing concerns, so pricing decisions get the attention of management only every so often.[11] Hence, a firm considers whether to change its product price only when demand or cost conditions are expected to move the actual markup significantly and persistently away from the profit maximizing markup. For instance, if higher nominal wages W, or lower productivity a were expected to compress the markup significantly and persistently, then it would be in the firm's interest to consider raising its product price to restore the profit maximizing markup.

These points can be summarized in four pricing principles:

1) Firms would like to keep their actual markup μ as close to the profit maximizing markup μ^* as they can over time, subject to the cost of changing their product prices.

2) Firms must balance the one-time cost of changing prices against the benefit of staying close to the profit maximizing markup over time.

3) A firm is more apt to change its product price to restore the profit maximizing markup the larger and more persistent it expects a deviation of its actual markup from the profit maximizing markup to be.

4) Firms move their prices with expected inflation on average over time.

The implications of these pricing principles for the economy-wide rate of inflation π may be summarized as follows:

$$\pi = INF(\mu_1, E\mu_2) + E\pi \tag{15}$$

where $E\pi$ is the expected trend rate of inflation, and $INF(\mu_1, \mu_2)$ is a function indicating the effect of the current and expected future markup on inflation.[12] When the current and expected future markup both equal the profit maximizing markup, then firms move their prices in accordance with expected trend inflation $E\pi$, i.e., $INF(\mu^*, \mu^*) = 0$. Markup compression ($\mu < \mu^*$) moves actual inflation above trend inflation, and markup expansion ($\mu > \mu^*$) moves actual inflation below trend inflation.

We characterize increasingly inflationary situations as follows:

A) Absolute Price Stability: $\mu_1 = E\mu_2 = \mu^*, E\pi = 0$. Current and expected future markups equal the profit maximizing markup, and expected trend inflation is zero.

[11] Calvo (1983) models price stickiness by assuming that a firm gets opportunities to change its price on a stochastic basis; this accords with the description of price-setting given here.

[12] Calvo's (1983) pricing model yields a forward-looking inflation process approximately like (15). See the discussions and derivations in Clarida, Gali, and Gertler (1999), Gali and Gertler (1999), Goodfriend and King (1997, 2001), and Taylor (1999).

B) Low Inflation Potential: $\mu_1 < \mu^*, E\mu_2 = \mu^*, E\pi = 0$. Current markup is compressed relative to the profit maximizing markup, but the expected future markup is not, and expected trend inflation is still zero.

C) Modest Inflation Potential: $\mu_1 < \mu^*, E\mu_2 < \mu^*, E\pi = 0$. Markup compression is expected to persist, but expected trend inflation is still zero.

D) Persistent Trend Inflation: $\mu_1 = E\mu_2 = \mu^*, \pi = E\pi > 0$. Current and expected future markups are at their profit maximizing levels, but expected trend inflation is positive.

Employment Fluctuations and the Markup

Inflation today is reasonably low and stable in the United States and around the developed world. Hence, we consider the nature of employment fluctuations in the NNS model in terms of situations A and B above. In other words, we suppose that the current markup may be compressed or elevated relative to the profit maximizing markup, but firms do not expect that gap to persist for very long. And firms expect zero inflation. The central bank is said to have "credibility for zero inflation" in these situations. When the central bank has credibility for zero inflation, firms are disinclined to raise or lower their product prices in response to a shock to their current markup because they expect the markup shock to be temporary.[13] In such circumstances, the current price level P is nearly invariant to current shocks or current monetary policy actions.[14]

In this case current employment and output are determined by the aggregate demand for goods. The reason is two-fold. First, each firm faces a downward sloping demand for its particular variety of consumption good, and a firm can sell only as much as households wish to purchase at the going price. Second, firms are happy to produce and sell as much as households are willing to buy because labor productivity exceeds the real wage. Hence, holding product price constant, profits rise with employment, production, and sales. Since firms can't sell more than demand will allow and firms are happy to accommodate demand, aggregate demand governs output in the short run, and output governs employment given labor productivity.[15]

We can understand the determination of employment in the benchmark NNS model from either a Keynesian or a classical perspective. The Keynesian

[13] Markup shocks are expected to be transitory because monetary policy is expected to make them so. See Sections 4 and 5 below.

[14] The price level is nearly invariant to current economic conditions because firms *choose* not to adjust their product prices to maintain markup constancy. Firms *would* adjust their prices to restore markup constancy if they expected that *otherwise* their markups would deviate persistently and significantly from the profit maximizing markup. Prices are less flexible in the NNS model the more confident are firms that monetary policy will manage nominal cost conditions so as to maintain their profit maximizing markup without any price adjustments. Hence, credibility for low inflation reinforces price stickiness in the NNS model.

[15] Blanchard and Kiyotaki (1987).

transmission mechanism runs from aggregate demand to employment. The production technology $c = an$ shows how employment n depends on aggregate demand c and labor productivity a. Firms attract enough labor to meet demand given labor productivity by offering a nominal wage W sufficient to induce households to supply the required labor input. Since the price level P is nearly invariant to current economic conditions, the higher nominal wage raises the real wage w. According to labor supply function (6) given aggregate demand c, a higher real wage increases labor supply by raising the opportunity cost of leisure. When demand falls and firms need less labor, wages fall since enough labor supply is forthcoming at a lower real wage.

The classical perspective takes the view that actual employment n must equal labor willingly supplied by households n^s *regardless of the strength of aggregate demand*. Working in this direction, substitute $c = an$ and $w = a/\mu$ into labor supply function (6), equate n and n^s, and solve for employment to arrive at

$$n = \frac{1}{1+\mu}. \tag{16}$$

From the classical perspective, employment in the NNS model is determined inversely with the markup, exactly as in the core RBC model.[16] The only difference is that firms adjust their prices continually to maintain a constant profit maximizing markup μ^* in the flexible price RBC model and markup constancy stabilizes aggregate employment in that case. When circumstances are such that the price level P is sticky in the NNS model, however, the markup fluctuates with the real wage and labor productivity according to (9), and employment fluctuates as well according to (16).

Employment varies inversely with the markup in (16) because the markup drives a wedge between the price of consumption goods and the marginal cost of production. In effect, the markup is a percentage sales tax administered by firms, the proceeds of which are distributed as profits to households. As is the case for any tax, a higher tax rate reduces the supply of the good being taxed, and a lower tax rate expands the supply of that good. Hence, a compressed markup expands (and a higher markup contracts) the production and sale of consumption goods. Alternatively, recall from (9) that a higher markup means a lower real wage relative to labor productivity; so the markup also acts like a tax on labor supply because it drives the real wage below the marginal product of labor. Thus, the labor market perspective provides another way of understanding why employment fluctuates inversely with the markup. The classical perspective is compatible with the Keynesian perspective because the markup shrinks when the wage rises to attract more labor in order to accommodate an increase in aggregate demand.

[16] Rotemberg and Woodford (1999).

It is useful to sum up this way: In the flexible price RBC model firms neutralize the effect of aggregate demand and productivity shocks on aggregate employment by adjusting their prices to maintain markup constancy. The flexible price RBC model is classical in the sense that aggregate output is determined independently of aggregate demand. We saw in Section 1 that the real interest rate adjusts in the flexible price RBC model to make household demand for aggregate consumption *conform* to the aggregate supply of consumer goods. In the NNS model, fluctuations in aggregate demand can *induce* fluctuations in employment and output. In that sense the NNS model is Keynesian. But since the NNS model has the classical RBC model at its core, we call it the new neoclassical synthesis, recalling Paul Samuelson's designation for the original attempt to synthesize classical and Keynesian economics in the 1950s. Since firms maintain the profit maximizing markup on average over time in the NNS model, the NNS model behaves like the flexible price RBC model on average but with leeway for monetary policy to influence aggregate demand and stabilize employment and inflation.

3. INTEREST RATE POLICY, CREDIBILITY, AND INFLATION SCARES

As is common practice, assume that the central bank implements monetary policy in the NNS model with a short-term nominal interest rate policy instrument R. By definition, the real interest rate r is $R - E\pi$, the money interest rate paid or earned on a loan above and beyond the compensation for expected inflation. In practice, a central bank's influence over the real interest rate is limited for two reasons. It exercises direct control of only the nominal rate. Expected inflation is variable, possibly highly variable if the central bank has little credibility for low inflation, so control of the nominal interest rate translates loosely into control of the real interest rate. Moreover, longer-term interest rates are what matter for economic activity, and a central bank influences long-term interest rates only indirectly via the management of its short-term nominal interest rate policy instrument. We ignore these important complications to focus on the essence of interest rate policy in what follows.

In order to understand the mechanism through which interest rate policy actions are transmitted to the economy, we must first specify the *context* in which policy is acting. Continue to assume that the central bank has credibility for zero inflation so that $E\pi = 0$ and the price level P is nearly invariant to current shocks and interest rate policy actions. In this case the central bank's choice of nominal interest rate target $\overline{R}$ translates into a target for the real interest rate $\overline{r}$. Moreover, in this case the public expects the future markup to be at its profit maximizing level $E\mu_2 = \mu^*$. Recall that current and future productivity (a_1, a_2) are given by technology, independently of interest rate policy. In this context, (13) says that expected future household consumption is *anchored by future income prospects* at $c_2^* = a_2 \frac{1}{1+\mu^*}$.

In order to trace the effect of an interest rate policy action on current macroeconomic variables, use (3) to express current desired consumption c_1 in terms of expected future consumption $c_2^* = a_2 \frac{1}{1+\mu^*}$ and the real interest rate target $\overline{r}$

$$c_1 = \frac{1+\rho}{1+\overline{r}} \cdot a_2 \frac{1}{1+\mu^*}. \tag{17}$$

Expression (17) reveals the nature of the leverage that interest rate policy exerts on aggregate demand: Current consumption c_1 is inversely related to the real interest rate target $\overline{r}$ when expected future consumption is anchored at $a_2 \frac{1}{1+\mu^*}$. An increase in the real interest rate target depresses current aggregate demand by raising the opportunity cost of current consumption in terms of future consumption. The contraction in aggregate demand is reflected in reduced current employment n_1, a low current real wage w_1, and an elevated current markup μ_1. Conversely, a cut in the real interest rate target expands current aggregate demand, raises the real wage, and compresses the markup. The transmission mechanism can be understood from either the Keynesian or the classical point of view. From the Keynesian perspective, interest rate policy exerts leverage over employment and output because production is demand determined in the short run. From the classical perspective, that leverage derives from the fact that aggregate demand influences wages, which in turn influence the markup, which behaves like a variable tax rate in the RBC setting.

The leverage that interest rate policy actions exert on employment creates the *fundamental credibility problem of monetary policy*. The credibility problem arises from a basic tension in the new neoclassical synthesis. On one hand, firms set their prices so as to maintain a profit maximizing markup on average over time. From the household's point of view, however, the markup acts like a tax on consumption and labor supply that reduces welfare. Therefore, the central bank has an incentive to pursue expansionary monetary policy on behalf of households to undo the markup tax. That temptation is greatest when the central bank's credibility for low inflation is *most* secure, since then employment can be expanded with little immediate increase in inflation or inflation expectations. The problem is that by giving in to this temptation the central bank undercuts its own credibility. If firms come to expect the markup to be compressed persistently, they will raise prices to restore the profit maximizing markup. Inflation and inflation expectations will rise, and the central bank will lose credibility for low inflation. In short, credibility for low inflation is fundamentally fragile in the new neoclassical synthesis because the public recognizes the central bank's temptation to pursue expansionary monetary policy to depress the markup and expand employment.[17]

[17] Barro and Gordon (1983), Chari, Kehoe, and Prescott (1989), and Sargent (1986) discuss credibility issues in models other than those of the new neoclassical synthesis.

From time to time the public comes to doubt the central bank's commitment to low inflation. The history of monetary policy in the United States contains numerous "inflation scares" marked by sharply rising long-term bond rates reflecting increased expected inflation premia.[18] Inflation scares create a fundamental dilemma for monetary policy. At the initial nominal interest rate target $\overline{R}$, expected higher inflation lowers the implied real interest rate target $\overline{r} = \overline{R} - E\pi$ and exacerbates the inflation scare by stimulating current demand and compressing the markup. The central bank could raise $\overline{R}$ just enough to offset the effect of expected higher inflation on the real rate. However, neutralizing the effect of higher inflation expectations on the real interest rate target does nothing to fight the collapse of credibility itself.

If the inflation scare persists, a central bank must react by raising its real interest rate target. That is, the central bank must raise $\overline{R}$ by *more* than the increase in $E\pi$. A higher real interest rate target counteracts the inflation scare by contracting current aggregate demand, reducing employment, lowering real wages, and widening the markup. According to (15), tight monetary policy works by elevating the current and expected future markup significantly above the profit maximizing markup. In the contractionary environment, firms move prices up more slowly than expected inflation, and expected inflation comes down as credibility for low inflation is restored.

Inflation scares are costly because ignoring them or raising $\overline{R}$ only enough to cover the increase in $E\pi$ can encourage even more doubt about the central bank's commitment to low inflation. But raising $\overline{r}$ to restore credibility for low inflation only works by contracting employment, output, and consumption to widen the markup significantly and persistently enough to encourage firms to slow the rate of inflation. For this reason, central banks have been reluctant to react promptly to inflation scares. In the past such hesitation led to "stagflation," when rising inflation encouraged by insufficiently preemptive policy would eventually be accompanied by a period of rising unemployment after the central bank set out to restore its credibility for low inflation.

4. FLUCTUATIONS AND STABILIZATION POLICY

In this section we consider three shocks that cause fluctuations in employment and output because firms choose not to adjust prices to maintain markup constancy. Again we assume that the central bank has credibility for low inflation. Inflationary situations A or B prevail, there are no inflation scares, and the current price level P is nearly invariant to current economic shocks and interest rate policy actions. We consider the effects of optimism or pessimism about future income prospects, a temporary productivity shock, and a shift in trend

[18] See Goodfriend (1993) and Chari, Christiano, and Eichenbaum (1998).

productivity growth. In each case we trace the effect of the shock holding the central bank's real interest rate target fixed, then we consider how interest rate policy might react to stabilize employment and inflation.

Optimism and Pessimism about Future Income Prospects

According to the analysis of consumption in Section 1, a household plans lifetime consumption to satisfy (3) and to exhaust its lifetime budget constraint (1). Using these two conditions, we can write current aggregate demand c_1 in terms of lifetime income prospects (y_1, y_2) and the central bank's real interest rate setting $\overline{r}$

$$c_1 = \frac{1+\rho}{2+\rho}(y_1 + \frac{y_2}{1+\overline{r}}). \tag{18}$$

Since current output and income are demand determined when the price level P is nearly invariant to current shocks and policy actions, we can set $y_1 = c_1$ in (18) and solve for c_1 in terms of y_2 and $\overline{r}$

$$c_1 = \frac{1+\rho}{1+\overline{r}} \cdot y_2. \tag{19}$$

According to (19), households transmit increased *optimism or pessimism* about future income prospects y_2 (whether in future wage or profit income) to current consumption, employment, and output. The reason is that households want to allocate any expected change in lifetime resources to both current and future consumption. Moreover, because current income is demand determined, there is a secondary (multiplier) effect on current income that amplifies the initial impact of increased optimism or pessimism about the future. Both the primary and secondary effects are captured in (19).

Although households react to increased optimism or pessimism by attempting to borrow or lend in the credit market, ultimately any change in current aggregate demand must be reflected in an equal change in current production. Collectively, households cannot borrow from the future to consume more in the present because it is impossible to bring goods forward in time. Nor is it possible to store goods for future consumption in this benchmark NNS model. However, the real interest rate does not react to conditions in the credit market because the central bank intervenes by injecting or draining cash to maintain its nominal interest rate target $\overline{R}$. In so doing, interest rate policy actually facilitates the transmission of optimism or pessimism about the future to current employment and output.

In principle, interest rate policy can counteract the effect on current employment and output of increased optimism or pessimism about the future. For instance, according to (19), a lower real interest rate target $\overline{r}$ can stabilize current consumption, employment, and output against increased pessimism about future income prospects. At best, however, stabilization policy can only be partially effective because it is difficult to recognize shocks promptly and because policy actions affect spending with a lag.

A Temporary Productivity Shock

Aggregate productivity grows on average over time as a result of technological progress. However, productivity growth fluctuates over time because the invention and implementation of technological improvements do not occur smoothly. We can think of a temporary shock to productivity as involving a period in which productivity grows more rapidly or more slowly than its long-run average, but is expected to return shortly to its long-run growth path. To analyze the effect of a temporary productivity shock in the benchmark NNS model, we abstract from trend productivity growth and consider a shortfall of current productivity a_1 with no effect on expected future productivity a_2.

The adverse shock to current productivity expected to be temporary has little effect on lifetime income prospects and, therefore, on current aggregate demand. Hence, the negative productivity shock causes firms to hire more labor to meet the initial demand. Real wages rise as firms bid for more labor. Household wage income rises at the expense of profit income, but aggregate real income remains largely unchanged.

The markup is compressed directly because lower productivity raises marginal cost and indirectly because the real wage is elevated. Firms are inclined to raise prices to restore the profit maximizing markup, but the price level does not change much if the negative productivity shock is not too large and is expected to be temporary.

Again the central bank can stabilize employment and inflation fully, in principle. According to (14) and (17), it does so by raising the real interest rate to contract current aggregate demand enough to stabilize the current markup at μ^*. When the markup is stabilized, current output, income, consumption, and the real wage all fall proportionally with productivity.

A Shift in Trend Productivity Growth

To understand the effect of shifting trend growth, suppose that current and future productivity are related by $a_2 = (1+g) \cdot a_1$, where g is the trend growth rate, and current productivity a_1 is taken as given. Assume that interest rate policy is expected to keep the actual markup at the profit maximizing markup in the future so that $\mu_2 = \mu^*$. In this case, future income prospects vary directly with the growth rate g since $y_2 = (1+g)a_1\frac{1}{1+\mu^*}$.

Shifting trend productivity growth affects current variables in the same way as changing optimism or pessimism about future income prospects. Substituting the above expression for y_2 into (19), we see that for a given real interest rate target $\bar{r}$, current aggregate demand, output, and employment all move in the same direction as the trend growth rate g. For instance, an increase in trend growth raises current aggregate demand, raises current labor demand, raises the real wage, and compresses the markup. Contrary to popular belief, an increase in trend productivity growth is inflationary at the initial real interest rate target because it compresses the current markup.

According to (14) the central bank can stabilize the current markup, employment, and inflation against a shift in trend productivity growth by moving its real interest rate target point for percentage point with the growth rate g. To see this, substitute $(1 + g)a_1$ for a_2 in (14) and note that $r^* \cong \rho + g$.[19] Higher trend growth requires a higher real interest rate target to give households an incentive not to consume the proceeds prematurely. Instead of providing a reason to keep interest rates low, higher trend productivity growth actually requires a higher real interest rate target on average over time to stabilize the markup and maintain credibility for low inflation.

5. WELFARE MAXIMIZING MONETARY POLICY

The benchmark NNS model presented here recommends that interest rate policy should stabilize the markup at its profit maximizing level in order to stabilize the price level and make employment and output behave as in the core RBC model with perfectly flexible prices. The recommended policy is referred to as "neutral" because it stabilizes the price level, neutralizes fluctuations in employment and output that would otherwise occur due to sticky prices, and makes aggregate demand conform to fluctuations in productivity as in a pure real business cycle.

Neutral monetary policy is recommended because it maximizes household welfare.[20] This can be understood in four steps:

1) The central bank can only stabilize the markup at the value that maximizes firm profits μ^*. Firm price adjustments will undo any attempt by the central bank to move the markup permanently away from μ^*.

2) It is feasible for monetary policy to stabilize the markup at μ^*. Interest rate policy can do so by making aggregate demand c conform to movements in productivity a given the production technology $c = an$ so as to stabilize employment at $n^* = \frac{1}{1+\mu^*}$.

3) Household labor supply n^s is invariant to productivity a when the markup is stabilized at its profit maximizing value μ^*. A greater abundance of consumption makes households want to take more leisure, but a higher real wage raises the opportunity cost of leisure just enough to neutralize the overall effect of productivity on desired labor supply. Thus, household

[19] The approximate one-for-one correspondence is an implication of log utility.

[20] Goodfriend and King (1997, 2001), Ireland (1996), and Woodford (2003).

welfare is maximized when consumption moves with productivity at the profit maximizing markup.

4) Household welfare would be reduced if monetary policy were to allow the markup μ to fluctuate around the profit maximizing markup μ^*. It is true that households would be better off in periods when the markup tax is low. But the markup tax would have to average as much time above as below μ^* to be consistent with firm profit maximization on average over time. With diminishing marginal utility, the utility gain from above average consumption and leisure would be insufficient to offset the utility loss from below average consumption and leisure. Among other things, such logic means that interest rate policy would reduce welfare if it moved the markup to smooth consumption against productivity shocks.

The key characteristics of neutral monetary policy are these:

First, neutral policy stabilizes employment at the "natural rate," $n^* = \frac{1}{1+\mu^*}$.[21] In effect, neutral policy enables the macroeconomy to operate as if firms adjusted their prices costlessly and continuously to maintain the profit maximizing markup at all times.

Second, when employment is stabilized at the natural rate n^*, actual output moves with "potential output" $y^* = an^*$, where potential output grows and fluctuates over time with productivity a. In other words, neutral policy aims to eliminate the "output gap," the difference between actual and potential output.

Third, the consistent pursuit of neutral policy perpetuates low inflation according to (15) if the central bank has already attained credibility for low inflation by its past policy actions.

Fourth, low inflation confers a number of benefits in addition to its consistency with neutral policy.[22] For instance, low inflation produces low nominal interest rates and less economization on the use of currency; low inflation minimizes costly pricing decisions; low inflation minimizes relative price distortions; and low inflation guards against disruptive inflation scares.

Fifth, a central bank can implement neutral policy by maintaining price stability. There is no need to target the profit maximizing markup directly in practice. The reason is that an economy in which firms show little inclination to raise or lower prices on average is one in which the profit maximizing markup is realized on average.

Sixth, price stability can be maintained by consistently raising the real interest rate target to preempt inflation and lowering it to preempt deflation. In practice, interest rate policy should utilize measures of the output gap, employment relative to the natural rate, and unit labor costs to help recognize and preempt potential departures from price stability.[23]

[21] Friedman (1968).

[22] Khan, King, and Wolman (2003).

[23] McCallum (1999).

Seventh, according to (14) the real interest rate target $\overline{r}$ that consistently achieves price stability shadows the real interest rate r^* that supports pure real business cycles. Price stability must be maintained by activist interest rate policy that makes aggregate demand conform to potential output to keep $\mu = \mu^*$, and makes the real interest rate move with expected productivity growth a_2/a_1.

Eighth, an inflation target facilitates the implementation of neutral monetary policy in three ways.[24] An inflation target mandated by the legislature helps secure credibility for low inflation against the temptation to stimulate employment excessively. A mandated target for low inflation reduces the incidence of destabilizing inflation or deflation scares. And an inflation target enables the central bank to cut its interest rate instrument more aggressively to stimulate economic activity when necessary without fear of an inflation scare.

6. CHALLENGES TO THE POLICY RECOMMENDATIONS

According to the benchmark NNS model, credible price stability keeps output at its potential and employment at its natural rate. So from this perspective even those who care mainly about output and employment can support strict inflation targeting. Yet the *benchmark* NNS model presented in this paper is only one of many possible specifications of the new synthesis model. Taking other features of the macroeconomy into account might overturn the strong implication that price stability is always welfare-maximizing monetary policy. The purpose of this section is to consider briefly three additional aspects of the macroeconomy and whether they call for optimal departures from strict inflation targeting.[25]

Nominal Wage Stickiness

Empirical studies of wage and price dynamics suggest that nominal wages exhibit about the same degree of temporary rigidity as do nominal prices.[26] Yet, nominal wages are perfectly flexible in the benchmark NNS model and are determined in perfectly competitive labor markets. So it is worth asking to what extent nominal wage stickiness might overturn the strict inflation targeting policy prescription. Consider a temporary adverse productivity shock. With flexible nominal wages, stabilization of the markup and the price level

[24] Bernanke, Laubach, Mishkin, and Posen (1999), Haldane (1995), Leiderman and Svensson (1995), and Svensson (1999).

[25] Goodfriend and King (2001) consider a number of reasons to depart from perfect markup constancy and price stability in an NNS model: fully dynamic multi-period pricing, distortions involving monetized exchange, variable labor supply elasticities, and government spending shocks. They argue that optimal departures arising from these sources are likely to be quantitatively minor.

[26] Taylor (1999).

calls for aggregate demand to contract proportionally with productivity. At the optimum, employment is unchanged because the markup is perfectly stabilized. The nominal and the real wage both fall with productivity, exactly offsetting the effect of lower productivity on marginal cost and the markup. And the economy settles temporarily at the reduced potential output with a perfectly stabilized price level.

Things don't work out as neatly if nominal wages are sticky. In order to maintain price stability, monetary policy must now steer output *below* potential. Monetary policy must push employment below the natural rate to offset the adverse effect of lower productivity on marginal cost. This is possible because labor is more productive at the margin the less it is utilized, i.e., there is diminishing marginal physical product of labor.[27] In the presence of nominal wage stickiness it is no longer feasible for monetary policy to both stabilize the price level and keep output at potential. In principle, then, a negative productivity shock could present the central bank with a short-run tradeoff between price stability and output stability (relative to potential) when both nominal wages and prices are sticky. In general, such a tradeoff would call for a departure from strict inflation targeting.

There are two reasons, however, why such situations should be of relatively little concern in practice. First, an inflation target between 1 and 2 percent per year and trend productivity growth of around 2 percent produces average nominal wage growth in the 3 to 4 percent range. Such high average nominal wage growth should keep the economy safely away from situations in which significant downward nominal wage rigidity, as opposed to slower nominal wage growth, is required to keep price inflation on target and output at its potential.[28] If the economy were to suffer a protracted productivity growth slowdown, then the central bank could stick to its inflation target and maintain markup constancy by allowing slower nominal wage growth to match the slower productivity growth. Downward nominal wage stickiness should not present a problem in this case. Upward nominal wage stickiness would not cause problems either. If nominal wages were temporarily rigid upward in the face of a favorable productivity shock, then the central bank could stick to its inflation target by steering the economy temporarily above potential output.

Second, implicit or explicit long-term relationships govern most labor transactions in developed economies. For reasons analogous to those discussed in Section 2, it can be efficient for firms to fix nominal wages for a period of time and to consider wage changes only at discrete intervals. Yet it would be inefficient for either firms or workers to allow temporary nominal

[27] Production technology (7) is specified as linear in labor for expositional purposes only. A more realistic specification such as $c = a(n)^{\alpha}$, $1>\alpha>0$, would exhibit diminishing marginal product of labor.

[28] Vinals (2001).

wage rigidity to upset the terms of otherwise efficient long-term relationships. And there is scope for firms and workers to neutralize the effect of wage stickiness since wages already resemble installment payments in the context of long-term relationships.[29] Hence, firms and workers could be expected to arrange future transactions to undo any effects of nominal wage stickiness.[30] If the price level is stabilized in the face of a negative productivity shock, those firms whose nominal wage is temporarily sticky will appear to pay an excessive real wage. However, this logic suggests that non-adjusting firms record a "due from" to be transferred from workers to the firm in the future. In this way, "effective" real wages fall as much for firms that do not adjust their nominal wages as for those firms that do adjust. To the extent that such behavior is widespread, there is little reason to depart from strict inflation targeting because nominal wages are sticky.[31]

From this perspective the consequences for monetary policy of stickiness in wages and prices are sharply different. We can expect firms and workers to *neutralize* the allocative consequences of temporarily sticky nominal wages in the context of long-term relationships in the labor market. But spot transactions predominate in product markets. There, temporarily sticky prices can cause the average markup to fluctuate significantly and persistently over time with adverse consequences for employment and inflation. The adverse consequences of temporarily sticky product prices need to be eliminated by *neutral monetary policy* that supports price stability.

Extreme Asset Price Fluctuations

Some analysts suggest that interest rate policy should react directly to asset prices in order to preempt extreme fluctuations such as those experienced in Japan and the United States in recent years.[32] They would urge a central bank to take such action even if it has full credibility for low inflation. Such advice amounts to a recommendation to risk recession or deflation in order to preempt what *may* become an unsustainable increase in asset prices. It is certainly debatable whether that risk would ever be worth taking.

The main problem with this recommendation, however, is that it is virtually impossible to put into practice.[33] The reason boils down to this: When asset prices *first* appear to be surprisingly elevated, the central bank is disinclined to react directly to them because asset prices are not yet so high as to be

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[29] Hall (1999).

[30] Barro (1977).

[31] Goodfriend and King (2001).

[32] Interest rate policy ordinarily takes indirect account of asset prices in so far as they help forecast aggregate demand.

[33] Bernanke and Gertler (1999), Goodfriend (2003), and Greenspan (2002).

clearly unsustainable. However, interest rate policy cannot react aggressively to asset prices *after* they become clearly unsustainable either. At that point a collapse of asset prices itself, even without a tightening of policy, could put the economy into recession. The best way to handle extreme fluctuations in asset prices is to make sure that supervisory and regulatory safeguards are in place to prevent a precipitous asset price correction from immobilizing financial institutions and markets, and to make sure that monetary policy is sufficiently sensitive to the risk of recession and deflation after a correction takes place.

The Zero Bound on Interest Rate Policy

This potential challenge to strict low inflation targeting stems from the fact that nominal interest rates cannot go below zero because neither banks nor the public will lend money at negative nominal interest when bank reserves and currency are costless to carry over time. The zero bound on nominal interest is a potential problem for monetary policy in a low inflation environment for two main reasons. First, if expected inflation is nearly zero, then the central bank cannot make *real* short-term interest negative if need be to fight deflationary shocks. Second, when short-term nominal rates are zero, further disinflation *raises* real short-term interest rates and worsens the deflationary pressure.

One could keep nominal short-term interest rates safely away from zero by targeting inflation at 3 or 4 percent per annum; but that would mean accepting the costs of excessive inflation forever. Moreover, such a high inflation target would invite credibility problems. An inflation target between 1 and 2 percent is a good compromise. Inflation is kept low, but far enough from zero to avoid deflation. One could conceivably raise the inflation target temporarily whenever more leeway for negative real interest was thought necessary to fight a recession. However, a policy that resorted to higher inflation in such circumstances would cause inflation expectations to rise whenever the economy weakened. Variable inflation expectations would be difficult to manage. Inflation scares would again become a significant source of shocks to the economy. Strictly targeting inflation between 1 and 2 percent could firmly anchor expected inflation and *still* give a central bank leeway to push the real short-term rate 1 to 2 percentage points below zero. Evidence from U.S. monetary history suggests that such leeway would be enough to enable a central bank to preempt deflation and stabilize the economy against most adverse shocks.[34] Moreover, other effective monetary policy options are available if short-term nominal rates become immobilized at the zero bound.[35]

[34] Reifschneider and Williams (2000) and Vinals (2001).
[35] Goodfriend (2000) and McCallum (2000).

7. CONCLUSION

Economists and central bankers will surely make further progress on the theory and practice of monetary policy in the future. Nevertheless, it seems clear that price stability will continue to be regarded as the foundation of good monetary policy. For almost two decades low and relatively stable inflation around the world has proved its worth. In the United States the period included the two longest peacetime cyclical expansions and two mild recessions in 1990–91 and in 2001. The benchmark new neoclassical synthesis model provides a theoretical case for price stability that supports the practical case derived from experience. Theory reinforces practice and strengthens the view that price stability should be a priority for monetary policy.

The benchmark NNS model explains why price stability works well, and why price stability is desirable from the perspective of household welfare. A credible commitment to low inflation prevents inflation or deflation scares that are destabilizing for both output and prices. Price stability is welfare-maximizing monetary policy because it anchors the markup at its profit maximizing value and thereby prevents fluctuations in employment and output that would otherwise occur due to sticky prices.

As an operational matter we saw how interest rate policy actions work to implement price stability by stabilizing the markup, and how interest rate policy secures credibility for low inflation. By anchoring *expected future* inflation we saw how such credibility strengthens the leverage that interest rate policy exerts over *current* aggregate demand. In so doing, credibility for low inflation helps monetary policy make aggregate demand conform to movements in potential output.

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How Do Central Banks Control Inflation?

Robert L. Hetzel

Around 1980, a dramatic change occurred in the intellectual consensus over the control of inflation. A consensus emerged that central banks are responsible for the behavior of inflation. Prior to then, most of the economics profession had viewed inflation as a hydra-headed monster, which sprang from innumerable sources.[1] Eclectic-factors theories of inflation, which explained inflation without any necessary reference to monetary policy, possessed an elaborate taxonomy of causes. Demand-pull inflation, which arose from excessive spending, could originate with government deficits or investment booms fueled by speculative activity. Cost-push inflation, which arose from the exercise of private monopoly power, could originate with labor unions or large corporations. Supply-shock inflation could come from weather, government regulation, or the restrictions imposed on oil exports by OPEC. Wage-price-spiral inflation emerged from inflationary expectations independent of monetary policy.[2]

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[1] For example, see Ackley (1961), Burns (1979), Blinder (1980), and the 1980 *Economic Report of the President,* Chapter 2, "Controlling Inflation." For a longer view, see Humphrey (1999). Velde (2004) argues that the older debate continues. He divides the current debate into two camps. One camp attributes the post-War behavior of inflation of monetary policy, and the other attributes it to the fortuitous behavior of real shocks.

Cagan (1974) borrowed the term, "hydra-headed monster," for a book on inflation (1974 *Economic Report of the President,* 21):

> During the 8 years the rate of inflation came in various forms—sometimes led by wages, sometimes by prices, by foods, by oil; sometimes it was domestic and sometimes imported. Many programs have been launched to stop it—without durable success. Inflation seemed a Hydra-headed monster, growing two new heads each time one was cut off.

[2] Goodfriend and King (1997, 236–7) commented on views of policymakers in the 1960s and 1970s:

> Policy advisers worried about a wage-price spiral and were concerned that inflation could develop a momentum of its own . . . [M]onetary policy was regarded as a powerful instrument, but one ill-suited to controlling inflation . . . While monetary policy could control

The hypothesis that inflation emerges from a wide variety of nonmonetary phenomena without the intermediation of central bank money creation implies that only infrequently is monetary policy the appropriate instrument to control inflation. The clash of a restrictive monetary policy and the powerful nonmonetary forces that drive inflation would, it was believed prior to 1980, force up interest rates. Although inflation would subside, the cost would be a socially unacceptable level of unemployment (Burns 1979). Only when all sorts of controls, formal and informal, failed to control inflation did governments turn to central banks to control inflation. As a last resort, they gave central banks instrument independence, that is, the independence necessary to move their instrument (the interbank rate) to whatever extent necessary to control inflation. Opinion changed when central banks not only succeeded in controlling inflation, but also did so at a socially acceptable cost.

What is special about central banks is their monopoly over the creation of the monetary base—the medium used to arrange for finality of payment. For this reason, the disastrous experiments with nonmonetary control of inflation prior to 1980 demonstrated that inflation is a monetary phenomenon. The quantity theory expresses this idea.[3] There are two hallmarks of quantity theory analysis. One is that the monetary transmission mechanism works through portfolio rebalancing. The other is that the price level is a monetary phenomenon.

Sections 1 and 2 exposit these ideas in a way that is applicable to central bank use of the interest rate as a policy variable.[4] If inflation is a monetary phenomenon, the policy procedures of the Federal Reserve possess a characterization in terms of monetary control.[5] However, such a characterization is not obvious. Because the Federal Open Market Committee (FOMC) uses the funds rate rather than the monetary base or bank reserves as its policy variable, money is endogenously determined. Furthermore, the minutes of FOMC meetings (Board, *Annual Reports*) suggest that the FOMC does not use money as an indicator variable, but instead appears to use a real variable, typically a growth gap or an output gap.[6]

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inflation in theory, the practical view was that inflation was mainly governed by psychological factors and momentum.

See also Hafer and Wheelock (2001).

[3] For an historical overview of the quantity theory, see Humphrey (1974).

[4] The central bank engages in whatever open market operations are necessary to achieve a value of the monetary base compatible with the adjustable peg it sets for the rate on lending in the interbank market.

[5] With an interest rate as the policy variable, monetary control does not imply an exogenous money stock. The monetary control that assures price stability provides for increases in the nominal quantity of money that equal the sum of two components. The first is the increase in real purchasing power demanded by the public that would occur with complete price flexibility. This increase abstracts from changes due to monetary shocks interacting with monetary nonneutrality. The second is the value of the central bank's inflation target. (See footnotes 11 and 12.)

[6] All statements about FOMC practices are inferences made by the author based on a variety of empirical studies and official records. The FOMC does not itself explicitly characterize its procedures.

Section 3 discusses FOMC procedures. Deflation and zero short-term interest rates in Japan have led some to question the ability of central banks to end deflation.[7] Section 4 discusses policy procedures that are robust to the zero-bound problem, that is, the inability of the central bank to lower the nominal interest rate below zero. Section 5 argues that the FOMC should formulate policy as a strategy for achieving explicit objectives.

1. REAL MONEY DEMAND AND PORTFOLIO BALANCE

Modern monetary economics began with the portfolio theory of money demand.[8] Money is one asset in a portfolio that includes bonds and capital. For the individual to be satisfied with the allocation of assets within his (her) portfolio, equality must hold between the rates of return to these assets. Formula (1) uses the portfolio balance equation in Friedman ("The Optimum Quantity of Money," 1969). The initial expression is the marginal rate of return to money. It is the sum of the marginal nonpecuniary services of money ($MNPS_m$) minus the cost imposed by expected inflation (π^*), or plus the return due to expected deflation. The second expression is the marginal return to bonds. The explicit yield paid on bonds is $r_{B,}$ and $MNPS_B$ is the marginal nonpecuniary services yielded by bonds. The third expression is the marginal return to physical capital. The explicit yield on capital is r_K, and $MNPS_K$ is the marginal nonpecuniary services yielded by capital.

$$MNPS_m - \pi^* = r_B + MNPS_B - \pi^* = r_K + MNPS_K \qquad (1)$$

All three assets yield liquidity services. The nature of these liquidity services is important for understanding the portfolio rebalancing that occurs from money creation that is independent of a prior change in money demand. The liquidity services yielded by money reduce transactions costs by economizing on time. For example, carrying additional money allows one to make cash

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Until 1980, the stability and low interest elasticity of the real M1 demand function rendered M1 a feasible indicator and target for monetary policy (Hetzel and Mehra 1989). The nationwide introduction of NOW accounts in 1981 made real M1 demand much more interest sensitive. This interest sensitivity made M1 unsuitable as a target for controlling the price level. To use M1 as an intermediate target for controlling inflation would have required setting its value based on a forecast of interest rates—a practical impossibility. Even with such a forecast, the policymaker would still have to estimate the magnitude of changes in real M1 demand due to changes in the opportunity cost of holding it. After the mid-1990s, sweep accounts made measurement of M1 impossible. In the early 1990s, M2 velocity rose when the public used small time deposits to purchase stock and bond mutual fund shares (Hetzel 1992). Since then, real M2 demand has also been highly interest sensitive.

Because central banks do not use money as an indicator or target, an "out of sight, out of mind" confusion about the role of money in price level determination can arise. The important point is that the nature of the public's demand for real money (degree of stability and interest sensitivity) possesses no implications for the nature (monetary or nonmonetary) of the price level.

[7] See Hetzel (2003a and 2004) for a discussion of Japanese monetary policy.

[8] For an overview, see McCallum and Goodfriend (1987).

purchases that otherwise would have necessitated a trip to the bank or the sale of an asset.

The liquidity services yielded by capital are nonmonetary in character. Liquidity now refers to the degree of access to credit. For example, a liquid asset can facilitate access to credit by furnishing collateral. Some assets (like inventories) are more liquid than are others (like buildings). Additional liquidity in the form of access to credit reduces the need for the liquidity offered by monetary assets. Goodfriend (2001) refers to the sum of the nonpecuniary services of money, bonds, and capital as broad liquidity.

One can use (1) to think about how the need for monetary control constrains the way that the central bank sets its interest rate target. That is, how does the central bank set its interest rate target ($r^T = r_B$) in a way that avoids money creation that sets off portfolio rebalancing by the public? The central bank must fulfill two conditions. The first is credibility for its inflation target. For example, if the public raises its expectation of inflation when the central bank lowers its interest rate target, changes in the interest rate target do not correspond to the same changes in the real (inflation-adjusted) interest rate.

Expressed generally, the second condition is that the central bank must vary its interest rate target in a way that respects the working of the price system. A central part of the price system is the real rate of interest. Movements in the real rate induce individuals to accept an unequal intertemporal distribution of consumption produced by the unequal intertemporal distribution of production. Fisher (1930) expressed the real rate of interest as the intertemporal price of consumption. One specific way to express this price is (2).[9] The real rate is rr. The subscripts indicate consumption in current and future periods. The constant rate of time preference that individuals possess for current over future consumption is ρ.

$$rr = (1+\rho)\left(\frac{c_2}{c_1}\right) - 1 \tag{2}$$

The natural rate of interest is the real interest rate that would exist in the absence of monetary disturbances. With the perfect price flexibility captured by the real business cycle core of the economy, the real rate of return on money, bonds, and capital would follow variations in the natural rate. To avoid monetary emissions that force portfolio rebalancing, the central bank must vary its interest rate target (r^T) so that the real value of its interest rate target tracks the natural rate. In doing so, it maintains equality across the asset yields in (1) at a level equal to the natural rate.

[9] The formula assumes log utility for consumers and certainty about the future (Goodfriend 2002). The formula for the real rate of interest in an economy with money includes terms that capture the value of the increased leisure (reduced shopping time) that derives from foregoing a unit of consumption by holding additional money balances.

The real world counterpart to the quantity theory conceptual experiment of an exogenous increase in money is a failure by the central bank to move its interest rate target in a way that tracks the natural rate. Assume, for example, that a rise in productivity growth makes the public believe that it will be better off in the future relative to the present. Because individuals desire to smooth consumption, they will want to consume more today. To prevent aggregate demand from exceeding the productive potential of the economy, the central bank must raise its interest rate peg in line with the natural rate.[10]

In contrast, assume that the central bank puts inertia into interest rate changes by smoothing the interest rate around a base value.[11] Interest rate smoothing (keeping the real rate below the natural rate) requires money creation. Monetary policy is expansionary.[12] However, this situation cannot persist (Friedman, "The Role of Monetary Policy," 1969). The increase in money that allows the divergence between the real and natural rates creates no additional productive capacity. Ultimately, the additional money creation will raise the price level, and the central bank will have to allow its interest rate target to rise fully to reflect the rise in the natural rate.[13]

2. THE PRICE LEVEL IS A MONETARY PHENOMENON

In the above example, the nominal quantity of money increased without a prior increase in the demand for the real quantity of money. The price level had to increase to maintain equilibrium in the market for the quantity of money. That is, the price level adjusted to endow the nominal quantity of money with the real purchasing power desired by the public.[14]

This section suggests a heuristic way to think about how a central bank limits money creation when it uses a short-term interest rate as its policy variable. Equivalently, one can ask how a central bank that uses the interest

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[10] Note that the increase in the interest rate raises the opportunity cost of holding money. That increase limits the increase in the public's demand for real money. By using the interest rate as its policy variable—as long as it successfully tracks the natural rate—the central bank allows the nominal quantity of money to change in line with changes in the demand for real money.

[11] The central bank can only smooth around a base that adjusts over time in line with the natural rate plus the central bank's inflation target. For example, the base value could equal an average of the prior period's interest-rate and the interest rate that would have existed in the prior period in the absence of monetary shocks (the prior natural rate plus the value of the inflation target).

[12] Expansionary monetary policy in combination with sticky prices stimulates real output temporarily. Adjusted for the trend, real output is high relative to its expected future value. The resulting expected fall in output keeps the real rate temporarily below the natural rate.

[13] Central bank policy actions occur as part of a strategy for achieving targets. This story assumes that the central bank allows drift in the price level (Goodfriend 1987; Hetzel 1995).

[14] The price level functions as part of the price system, that is, to clear markets. For a small country with a pegged exchange rate, changes in the price level equilibrate the balance of trade. An empirical implication of the quantity theory is that changes in the price level serve different roles for countries under fixed, rather than floating, exchange rates.

rate as a policy variable provides a "nominal anchor," so that the price level possesses a unique equilibrium value.[15]

The answer offered in Section I is that the central bank must tie down the way that the public forms its expectation of the future price level. It must also set its interest rate target in a way that tracks the natural rate. The Fisher (1907) formula summarizes these two tasks.

The nominal interest rate, which is the exchange rate between current and future dollars, is the product of the two factors shown in (3). The first is the (gross) real interest rate, which is the real exchange rate of current for future goods. The second is the ratio of the expected future price level to the current price level (asterisk indicates expected).[16]

$$r_t = (1 + rr_t)\,\frac{P^*_{t+1}}{P_t} - 1 \tag{3}$$

The nominal-real distinction gives (3) content by explaining which variable the central bank must control and which variable it must accept as given by the price system. In the rearrangement of (3) as (4), the superscript N on the real rate indicates the natural rate (the value that obtains with complete price flexibility). To control money creation in a way that is consistent with its inflation objective, the central bank must make the expectation of the future price level (P^*_{t+1}) conform to its inflation target.[17] The central bank must also move its interest rate target (r^T_t) with changes in the natural rate (rr^N_t).

$$P_t = \left(\frac{1 + rr^N_t}{1 + r^T_t}\right) P^*_{t+1} \tag{4}$$

As long as the central bank maintains the two right-hand factors of (4) unchanged, it will stabilize the inflation rate. Expectations will then drive money and prices. Money will increase at a rate given by the sum of the central bank's inflation target and the growth rate of real money demand consistent with price flexibility (or with no monetary shocks).[18]

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[15] The welfare of individuals depends only upon real variables (physical quantities and relative prices). It follows that only the central bank can give nominal variables well-defined equilibrium values. The price level is a nominal variable—the money price of goods. (The number of dollars required to purchase a standardized basket of goods.) The seminal work on nominal determinacy in a monetary regime of interest rate targeting is in Sargent and Wallace (1974), Dotsey and King (1983) and McCallum (1986).

[16] Formula (3) is an approximation.

[17] With base drift in prices, the central bank ties down the way that the public forms its expectation of the future price level in response to shocks rather than the expectation itself (McCallum 1986; Goodfriend 1987; Hetzel 1995).

[18] Write the equation of exchange using percentage changes.

$$\dot{M} = \pi + \dot{k} + \dot{y}, \tag{5}$$

3. FOMC PROCEDURES: INTEREST RATE AND GROWTH GAPS

To understand the procedures that the central bank uses to track the natural rate and, in the process, to control money creation, one needs to think about gaps between the real rate and the natural rate. The assumption that the price level is a monetary phenomenon implies that such gaps are "transitory." Changes in the price level will undo the changes in real money that permit the gaps. At the same time, the assumption that a gap can exist at all requires some power by the central bank to alter real money and force portfolio rebalancing by the public. One needs a theory of monetary nonneutrality to explain this power and to give content to the characterization of "transitory." To avoid interrupting the flow of the discussion of monetary policy procedures, I have placed a discussion of monetary nonneutrality in Appendix B.

How does the central bank move the funds rate in a way that eliminates real-rate/natural-rate gaps? In principle, it could respond to deviations of the price level from a targeted value. Long lags, evidenced by the length of time between the initiation of an expansionary monetary policy and the onset of inflation, could make that procedure destabilizing (Friedman 1960). In principle, the central bank could solve a model of the economy with a real business cycle core to determine the natural rate that would exist with complete price flexibility. A credible central bank could then set its interest rate peg at a value equal to the sum of the natural rate and its inflation target. In practice, the necessary models do not exist.

Policymakers must fall back on some indicator. Over a time period that varies positively with the degree of instability in money demand, they could look for changes in the trend rate of growth of money. However, noise in money demand and also the interest sensitivity of money demand has meant, in practice, that the interval of time required to ascertain that a change in trend money growth has occurred is impracticably long.

In practice, the FOMC appears to use a growth-gap indicator: the difference between actual "underlying" real growth and trend real growth.[19] "Underlying" growth abstracts from transitory influences on real growth such as weather and strikes. Under this interpretation of monetary policy setting, the FOMC assesses the reliability of its estimate of the growth gap by observing

where M is money; π, inflation; k, the inverse of the income velocity of money; y, real output; and the dot indicates a percentage change. As a consequence of its interest rate peg, the central bank accommodates changes in the public's demand for real money $(\dot{k} + \dot{y})$. The assumption that the central bank varies its interest rate peg so that the real rate equals the natural rate implies that no monetary emissions occur that require a change in inflation different from the central bank's target. Given credibility, expected inflation will equal the central bank's inflation target, which will then control both inflation and money growth (beyond changes to real money demand).

[19] The statements here come from the documentary and empirical evidence in Hetzel (2004c). See comments in Appendix A and footnotes 6 and 7.

measures of change in excess capacity, especially, the unemployment rate. For example, if the growth gap is positive, the unemployment rate should be falling. The FOMC moves the funds rate above its prevailing value in response to a positive growth gap, and conversely.

The FOMC appears to use this pragmatic search procedure for changing the funds rate to discover the natural rate.[20] It can do so because there is a correspondence between the real rate/natural rate interest gap and the growth gap. Failure of the central bank to align the real rate that corresponds to its interest rate peg with the natural rate allows a growth gap to emerge.

These procedures for tracking the natural rate require that the public's expectation of inflation be stable at a value equal to the central bank's target for inflation. A major innovation of the post-1979 operating procedures was the emphasis on credibility. The FOMC raised the funds rate in response to sharp increases in bond rates construed as indicating a rise in inflationary expectations to a level inconsistent with its implicit inflation target. Goodfriend (1993) documents these episodes of "inflation scares." Note that the FOMC apparently does not target directly a discrepancy between actual and targeted inflation, but rather between expected and targeted inflation.[21]

4. THE ZERO BOUND PROBLEM

The zero-bound problem refers to the fact that there is a lower bound of zero on nominal interest rates. If an expectation of deflation exists, the negative value of that expectation places a floor on the real rate of interest. The central bank can lose its ability to track the natural rate if it falls below this floor. In this situation, the central bank can continue to stabilize the price level by changing from an interest rate to a reserves instrument.

Consider again FOMC procedures for setting an interest rate instrument. To achieve its inflation objective, the FOMC requires procedures for discovering the associated unique "nominal natural rate of interest." With credibility, this interest rate equals the value of the central bank's inflation target plus the natural rate. The central bank uses its growth gap procedures to discover the value of the natural rate.

Consider now the analogue of these procedures for a reserves instrument. A trend rate of growth of reserves exists that varies positively with the trend rate

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[20] Economists often characterize as "activist" a monetary policy that uses a measure of real economic activity, such as an output gap, as an indicator variable for adjusting an interest-rate peg (for example, Orphanides 2003a). However, real variables offer information on the natural rate of interest. Tracking the natural rate with procedures that use real variables as indicators is more aptly characterized as a "neutral" policy. Such a monetary policy respects, rather than supplants, the working of the price system.

[21] What is relevant for current price-setting behavior is expected inflation. Orphanides (2003c) concludes that the FOMC targets expected inflation.

of growth of real output. There is a corresponding rate of reserves growth that equals this rate plus the targeted inflation rate. Analogous to the interest rate case, the central bank could use a growth gap indicator to adjust judgmentally reserves growth rates up or down from the prevailing value to keep the growth gap equal to zero on average over time. In this way, the FOMC would maintain reserves growth equal to the reserves demand consistent with trend real growth and targeted inflation.

In the case of an interest rate instrument, the central bank privatizes control over reserves provision by turning the decision on the quantity of reserves over to the financial market (subject, of course, to setting both the funds rate and the public's expectation of inflation consistently with its inflation target). It takes direct control over the setting of the interest rate. In the case of a reserves instrument, the central bank turns (real) interest rate determination over to the private market while taking direct control over reserves provision.[22] There is no clear economic reason for preferring a reserves instrument to an interest rate instrument except for the advantage of the former in dealing with the zero bound problem.[23]

Critics of quantitative procedures for the implementation of monetary policy have argued that the central bank becomes impotent to force portfolio rebalancing and stimulate expenditure at a low or zero interest rate. The public will supposedly hoard the money the central bank creates through open market purchases.[24] The idea of a liquidity trap gains apparent plausibility from the fact that at a zero short-term interest rate money and short-term government securities are perfect substitutes because both pay no interest. (At the margin, money ceases to yield more liquidity services than bonds.) However, the liquid assets in the public's portfolio then become the total of money and bonds. The central bank can still increase liquidity through purchases of illiquid assets that increase this total. That increase will stimulate expenditure because the public will not forego the holding of income-yielding assets for assets whose marginal yield is zero.

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[22] The reserves targeting procedures could include a tolerance band for allowable interest rate fluctuations. However, just as in the case of the gold standard before the establishment of the Fed, volatility of short-term rates would not pass on to long-term rates.

[23] According to the logic laid out in Poole (1970), reserves control would produce the changes in real rates required by real shocks faster than with interest rate control. Interest rate control would accommodate changes in the demand for real money with changes in money faster than with reserves control.

[24] The idea of a liquidity trap goes back to Keynes. In comparing classical and Keynesian economics, Mundell (1968, Chapter 12) referred to the tradition of "classicists and romanticists." For Keynesians (romanticists), the issue was not how to limit aggregate demand to the production of goods and services, but rather how to increase production by increasing aggregate demand through deficit spending. With respect to a liquidity trap, the "romanticist" position is that a liquidity trap allows costless (noninflationary) seigniorage. When the central bank exchanges non-interest-bearing government debt (money) for interest-bearing government debt (bonds), the public simply hoards the additional money.

Consider again the portfolio balance equation (1), with $r_B = MNPS_m = MNPS_B = 0$, and $-\pi^* = r_K + MNPS_K$. Assume that the central bank purchases an illiquid asset—for example, shares in a mutual fund holding equities. The public will rebalance its portfolio through the purchase of physical assets like land and equities. The rise in their price will raise their value as collateral ($MNPS_K$ rises while r_K falls) and thus facilitate the access to credit of the holders of these assets. Increased liquidity from increased access to credit augments the portfolio rebalancing effect by decreasing the demand for the liquidity services of money. The increase in the price of physical capital relative to its replacement cost stimulates investment.[25]

5. RULES VERSUS DISCRETION

Robert Lucas (1981, 255) expressed the prevailing consensus in academia about the desirability of basing policy on an explicit strategy.

> [O]ur ability as economists to predict the responses of agents rests, in situations where expectations about the future matter, on our understanding of the stochastic environment agents believe themselves to be operating in. In practice, this limits the class of policies the consequences of which we can hope to assess in advance to policies generated by fixed, well understood, relatively permanent rules (or functions relating policy actions taken to the state of the economy)....[A]nalysis of policy which utilizes economics in a scientific way necessarily involves choice among alternative stable, predictable policy rules, infrequently changed and then only after extensive professional and general discussion, minimizing (though, of course, never entirely eliminating) the role of discretionary economic management.

Lucas (1981, 255) also noted:

> I have been impressed with how noncontroversial it [the above argument for rules] seems to be at a general level and with how widely ignored it continues to be at what some view as a "practical" level.

One problem with moving to a rule that incorporates an explicit strategy is a lack of agreement over those aspects of monetary policy that have rendered policy largely stabilizing since the early 1980s. The FOMC could make policy in a way that leaves a record that allows learning about the systematic aspects

[25] For further discussion, see Goodfriend (2001) on broad money. The transmission of the impact of monetary policy on the spending of the public continues to operate through asset prices and interest rates, but one must consider a range of assets broader than Treasury bills (Brunner and Melter 1968). Reserves, rather than the funds rate, become the policy instrument.

of policy. Such learning would require that the FOMC make an ongoing effort to record the systematic part of monetary policy and deviations from it.[26]

The FOMC would begin by making its inflation objective explicit. The FOMC secretary would then take responsibility for distilling the strategy most representative of FOMC practice in achieving that objective. This strategy would organize discussion of the Bluebook.[27] The Bluebook would make explicit the behavior of whatever indicators the FOMC uses regularly. The Greenbook would predict the behavior of the future funds rate path based on the FOMC's inflation objective and on the strategy chosen by the Bluebook as most representative of FOMC practice.[28]

The Bluebook would also assess recent past actions of the FOMC in terms of the strategy assumed representative of FOMC behavior. In particular, it would flag deviations from the assumed strategy arising from one-time special factors and events. Deviations might include financial market instability and the foreign exchange value of the dollar. Finally, the Bluebook would make regular assessments of the reasons for missing the FOMC's objectives.

6. SUMMARY

If the price level is a monetary phenomenon, then the way that the central bank controls monetary base and money creation determines the behavior of inflation. Even when a central bank does not employ reserves as an instrument or money as an indicator, its operating procedures possess a characterization in terms of monetary control. The central bank achieves that control by keeping the public's expectation of inflation equal to its inflation target and by varying the funds rate in a way that causes the real interest to track the natural rate. This tracking emerges from procedures that move the funds rate away from its prevailing value in response to an estimated growth gap.

By maintaining expected inflation equal to its inflation target, money and inflation grow in line with the inflation target. By maintaining the real rate of interest equal to the natural rate, the central bank prevents monetary emissions that force undesired changes in prices.

[26] The answer to the question posed in the title to this article ("How Do Central Banks Control Inflation?") depends upon the strategy central banks follow. This proposal, if adopted, would make that strategy explicit.

[27] The staff of the Board of Governors circulates the Bluebook prior to FOMC meetings. It suggests alternative FOMC directive language and presents arguments supporting the alternatives.

[28] The Greenbook, which the Board staff circulates prior to FOMC meetings, contains forecasts of macroeconomic variables. These forecasts are judgmental.

APPENDIX A: MONETARY POLICY PRE- AND POST-VOLCKER

Prior to 1979 and Paul Volcker's chairmanship, the FOMC used the output gap (the difference between actual and trend output) as an indicator for setting the funds rate. The FOMC raised the funds rate only when an estimated negative output gap approached zero. It benchmarked the level of the trend line for real output using a year in which full-employment prevailed, assumed to be 4 percent. However, because 4 percent turned out to be too low an estimate, the FOMC consistently overestimated the appropriate height of the trend line for real output (Mayer 1999; Orphanides 2003b and 2003c). Phillips curve estimates of inflation based on overly pessimistic estimates of the output gap produced forecasts for inflation that were consistently too low (Orphanides and van Norden 2003). The assumption that inflation arose from real forces unrelated to monetary policy caused the FOMC to accept historically high inflation rates as necessary to avoid a high level of unemployment.

In the early 1980s, the FOMC began to rely on an estimate of the gap in the growth rate of real output relative to potential output. Starting in the 1980s, "bond market vigilantes" forced bond rates up whenever real output grew strongly. The sensitivity of the FOMC to bond rates as indicators of inflationary expectations meant that the FOMC raised the funds rate whenever economic activity quickened.

A search of FOMC transcripts and staff materials circulated to the FOMC for the years 1983 through 1997 revealed only very infrequent mention of an output gap. There was a single reference in FOMC meetings in each of the years 1988, 1992, 1993, and 1994 and three references in 1995 and 1996. In contrast, the use of the term "sustainable" as a characterization of the desirable growth rate of output was ubiquitous. For example, the Directive issued at the January 28, 2004, FOMC meeting stated, "The Federal Open Market Committee seeks monetary and financial conditions that will foster price stability and promote *sustainable growth in output*" (italics added).

Hetzel (2004b) relates changes in the funds rate to a proxy for the growth gap. For the period from 1982 on, Orphanides (2003c) finds that a growth gap does a better job than an output gap in explaining the behavior of the funds rate. For the earlier stop-go period, the output gap is superior. Mehra (2002) finds evidence for both sorts of gaps in the latter period.

With the establishment of full credibility after 1995, the FOMC gained more latitude in moving the funds rate. This would allow a departure from growth gap procedures beginning with the Asia crisis in fall of 1997. Credibility gives the FOMC the latitude to wait before raising the funds rate until growth has reduced the magnitude of the current negative output gap.

APPENDIX B: MONETARY NONNEUTRALITY

Monetary nonneutrality arises from a coordination failure.[29] When the central bank creates and destroys money in an erratic way that forces unpredictable changes in the price level, individual price setters lack a coordinated way to move their dollar prices to maintain the real purchasing power desired by the public while also preserving relative prices. Individual price setters do not capture the externalities from being the first to change their dollar prices to discover the price level that would prevail with perfect price flexibility. They therefore make quantity adjustments initially.

As explained by Friedrich von Hayek (1945), in competitive markets the price system allows the efficient allocation of resources by communicating information widely dispersed among individuals. The individual firm can set its output based only on the market price for its product and the prices of its labor and capital inputs. The price system fails to provide any comparable mechanism for economizing on the information needed to move individual dollar prices to the level appropriate for providing the real purchasing power the public desires.

When a firm (with some transitory market power) sets the dollar price of its product, it is solely concerned with the ratio of its dollar price to other dollar prices. That is, it only cares about relative prices—the rate of exchange of its product with other products. However, there is another dimension to its dollar price. The average of the dollar prices set by firms must be at the level that endows the nominal quantity of money with the real purchasing power that the public desires. How do individual firms set their dollar prices in a way that collectively creates the right amount of purchasing power?

The coordinating mechanism that maintains the average of individual dollar prices at the level that delivers the public's desired purchasing power is a common expectation of the future price level. Of course, the central bank must validate that expectation by pursuing a monetary policy resulting in a consistent rate of money creation. The main responsibility of a central bank is to provide this coordination for the setting of dollar prices. The more explicit the central bank is about its inflation objective, the better it fulfills this responsibility.

What happens when erratic money creation by the central bank forces unpredictable changes in the price level? For example, assume that the central bank attempts to lower equity prices through a "high" real interest rate made possible by money destruction. The central bank provides no guide for the

[29] Ball and Romer (1991) explain monetary nonneutrality using a model of fixed menu costs and coordination failure.

duration of the policy or the required fall in asset prices. A specific example would be Fed policy in 1928 (Friedman and Schwartz 1963). The resulting monetary contraction will require a lower price level, but the nature of the policy renders the ultimate price level unpredictable. Associated changes in real money demand produced by interest rate and real output changes and financial market instability will likely render money an unreliable guide to the appropriate price level.

Consider an individual firm. Assume that its customers face search costs so that the firm possesses some short-term, but no long-term, market power. If the firm lowers its price in the absence of an aggregate shock, it will expect initially only a small increase in demand. Profits will fall because the firm sells about the same amount, but at a lower price. However, over time, demand will increase. If the firm's price was appropriate before, it will then sell too much. While its sales increase, it sells each unit of output at a loss.

Given monetary contraction, all firms should lower their dollar prices in tandem to maintain sales. However, there is no way to coordinate a common fall in dollar prices that preserves relative prices. Each individual firm faces the prospect of lowering its price in an isolated fashion and incurring the losses described above. Another way to make this point is to note that the firm that lowers its price first confers a positive externality by increasing the purchasing power of money.

This story of price stickiness captures the spirit of the Friedman-Lucas (Lucas 1972) critique of the Phillips curve understood as a menu of choices between inflation and unemployment. Unanticipated changes in aggregate nominal demand created by the central bank affect real output while anticipated changes do not. Anticipated changes are those associated with a common expectation of inflation consistent with central bank monetary policy (money creation). For example, inflation consistent with an announced, credible inflation target will not affect output. The common expectation set up by the central bank guides firms in setting their dollar prices in a coordinated way to preserve real purchasing power while allowing freedom to set relative prices.

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Predicting the Recent Behavior of Inflation Using Output Gap-Based Phillips Curves

Yash P. Mehra

Many analysts believe that strong productivity growth has played an important role in the favorable inflation performance of the U.S. economy since the mid-1990s. Inflation, as measured by the behavior of the GDP deflator, hovered mostly near a low of 2 percent in the second half of the 1990s and has decelerated further during the past three years. Some policymakers think that, as a result of the continuing strong productivity and weak labor market, inflation may remain low throughout 2004, despite the continued strong pickup in economic activity.[1]

The traditional output gap-based Phillips curve relates current inflation to lagged inflation, supply shocks, and a measure of excess demand such as the level of the output gap. This Phillips curve is likely to overestimate inflation in the second half of the 1990s unless one revises upward estimates of real potential output made possible by the ongoing acceleration of productivity growth. However, in recent speeches, a few policymakers have highlighted two other potential anti-inflationary consequences of the recent surge in productivity. One is that the recent surge in productivity accompanied by weak labor markets has reduced unit labor costs, leading to possible downward pressures on inflation.[2] The other potential consequence stems from the ensuing

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[1] See, for example, recent speeches by Bernanke (2003, 2004).

[2] Fed Governor Ben Bernanke (2004), among others, has emphasized this factor in the recent evolution of inflation, as he observes:

> Recently . . . labor productivity has grown even more quickly than the cost of employing workers, with the result that unit labor costs have declined in each of the past three

behavior of aggregate demand. The strong productivity growth and the resulting surge of real potential output imply aggregate demand must grow fast enough to absorb higher potential output. Otherwise, disinflationary pressures may develop.[3]

In order to investigate the above-noted potential anti-inflationary consequences of acceleration of productivity, this article augments the traditional output gap-based Phillips curve to include two additional variables: the cyclical component of a markup variable defined as the markup of prices over unit labor costs and the change in the output gap. The markup allows for the short-term influence of a productivity-induced decline in unit labor costs on inflation, whereas the "rate of change" specification implies inflation depends also on how fast aggregate demand is growing relative to potential (called here the "demand growth gap"). I estimate the modified Phillips curve and examine whether it predicts the recent deceleration of inflation.[4] I also examine the robustness of the results of using wage share, rather than the markup, to capture the short-term influence of productivity-induced decline in unit labor costs on inflation.[5]

Some analysts have argued that Phillips curves are not useful for predicting inflation. In particular, Atkeson and Ohanian (2001) present evidence indicating that one-year-ahead inflation forecasts from several NAIRU (nonaccelerating-inflation rate of unemployment) Phillips curves are no more accurate than those from a naïve model that predicts inflation next year will be the same as it had been over the past year. Sims (2002) points out that the results in Atkeson and Ohanian arise entirely from having the forecast evaluation period restricted to 1984–1999, a period when inflation was very stable. I examine the robustness of the results in Atkeson and Ohanian along another dimension. Their forecasting exercise predicts the one-year-ahead inflation rate conditional on just past values of a real activity variable and the inflation rate, thereby ignoring the potential contribution of the future values

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> years. . . . A decline in production costs must result in lower prices for final consumers, an increase in price-cost markup for producers, or both ("Monetary Policy," 3).

Ball and Moffitt (2001) have also emphasized the role of weak labor markets in explaining the recent behavior of inflation.

[3] See, for example, Kohn (2003), who argues that, as a result of the "jobless recovery," rapid productivity growth has been associated with weak growth in aggregate demand, resulting in a falling inflation rate.

[4] It should be noted that the hypothesis that inflation may depend on a change in the output gap is not new. Gordon (1983), in fact, uses such a Phillips curve to explain U.S. inflation dynamics over almost a century from 1892 to 1980. The role of such a Phillips curve in explaining the most recent inflation dynamics is, however, left unexplored. Similarly, the hypothesis that inflation may be influenced by unit labor costs is not new either, having been previously examined by Gordon (1988) and Mehra (1991, 1993, 2000), among others. The empirical evidence in previous research on the importance of unit labor costs in explaining inflation has, however, been mixed, as I find even here.

[5] Many analysts argue that labor share can better capture the influence of the productivity-led decline in unit labor costs on inflation. See, for example, Galí and Gertler (2003).

of real activity over the forecast horizon.[6] Their exercise may be a reasonable way to construct the forecast because, in real time, forecasters usually do not have information about the future values of the indicator variable. However, it is plausible that a forecast including this extra information may be more accurate than the one ignoring it. As a robustness check, I take the other extreme and generate one-year-ahead predictions of the inflation rate under the counter-factual assumption that the forecaster knows actual values of the indicator variable over the forecast horizon. I then investigate whether the Phillips curve still generates less accurate predictions of the inflation rate than does the naïve model.

The empirical work presented here estimates the modified Phillips curve over two sample periods, 1961Q1 to 1995Q4 and 1961Q1 to 2003Q4, using the chain-weighted GDP deflator as the measure of inflation.[7] It suggests the following conclusions. First, the estimated coefficients that appear on the output gap and its rate of change are significant and correctly signed, suggesting there is a "rate of change effect." Inflation is predicted to rise when the output gap is positive and when aggregate demand increases faster than real potential output. Second, the markup, which is usually defined as the excess of the price level over unit labor costs, has a slow-moving trend and is not statistically significant when included in the estimated Phillips curve. However, the cyclical component of the markup when included in the Phillips curve is significant and appears with a negatively signed estimated coefficient, meaning inflation is predicted to fall if the cyclical markup is high. If the Phillips curve includes the wage share instead of the markup, the estimated coefficient on the wage share is positive, suggesting inflation is predicted to fall if the wage share declines.

Third, the predictions of the one-year-ahead inflation rate conditional on actual values of the explanatory variables suggested by traditional and modified Phillips curves track actual inflation well, outperforming those based on the naïve model that predicts inflation using only its past values.[8] This result holds over 1980–2003 as well as over 1984–1999, a period when inflation was stable. The results also indicate demand growth and output gap variables help most in generating accurate predictions of the inflation rate. The markup (or the wage share) does not improve the predictive accuracy if it is included in

[6] Their forecasting exercise also assumes that the NAIRU is constant over the sample period 1959–1999, because one of the indicator variables used is the unemployment rate, not the unemployment gap.

[7] In order to check whether results regarding the influences of additional factors on inflation are not simply due to the ongoing episode of productivity surge, the shorter sample period exludes the most recent period of productivity surge.

[8] The predictions, however, are dynamic in the sense that lagged values of the inflation rate used are those predicted by the model.

the modified Phillips curve. Together these results suggest that Phillips curves are useful for predicting inflation.

Regarding sources of the recent deceleration of inflation, the correlations summarized in the estimated modified Phillips curve suggest one plausible explanation of the recent behavior of inflation. As noted at the outset, inflation, after hovering near a low of 2 percent in the second half of the 1990s, decelerated further during the past three years. In the second half of the 1990s, the demand growth gap stayed close to the 2 percent range, as aggregate demand grew just fast enough to absorb the productivity-induced increase in potential. However, during the period 2000–2002, aggregate demand did not grow fast enough to absorb higher potential output, creating a declining demand growth gap and negative output gap. The recent deceleration is well predicted by the behavior of a Phillips curve that includes these two gap variables. However, the contribution of the markup (or wage share) in improving the prediction of the inflation rate since the mid-1990s remains negligible, suggesting the markup is not providing information beyond that contained in the gap variables. These results suggest that the weak demand growth gap together with the resulting negative output gap trump the cyclical markup (or wage share) as the major source of the recent deceleration of inflation.

The plan of this article is as follows. Section 1 discusses two modifications to the conventional expectations-augmented Phillips curve. It also provides an overview of the data including graphs of key variables that enter the Phillips curve, the estimation procedure, and the empirical specifications estimated here. Section 2 presents the new empirical work, and Section 3 contains concluding observations.

1. MODEL AND THE METHOD

Traditional and Modified Phillips Curves

The traditional reduced-form Phillips curve relates current inflation to lagged inflation, supply shocks, and a measure of excess demand such as the level of output or unemployment gap. Following Gordon (1985, 1988) and Stockton and Glassman (1987), the traditional output gap-based Philips curve can be derived from the following reduced-form price and wage equations.

$$\Delta p_t = h_0 + h_1 \Delta (w - q)_t + h_2 x_t + h_3 sp_t, \tag{1.1}$$

$$\Delta \left(w - q\right)_t = k_0 + k_1 \Delta p_t^e + k_2 x_t + k_3 sw_t, \text{ and} \tag{1.2}$$

$$\Delta p_t^e = g(L) \Delta p_t, \tag{1.3}$$

where all variables are in natural logarithms and where p is the price level; w is the nominal wage; q is labor productivity; x is a demand pressure variable;

p^e is the expected price level; sp represents supply shocks affecting the price equation; sw represents supply shocks affecting the wage equation; $g(L)$ is a lag operator; and Δ is the first difference operator. Equation (1.1) describes the price markup behavior: prices are marked over productivity-adjusted wage costs and are influenced by cyclical demand and the exogenous supply shocks. This equation implies that productivity-adjusted wages determine the price level, given demand pressures. Equation (1.2) is the wage equation: wages are assumed to be determined by cyclical demand and expected price level, the latter modeled as a distributed lag on past prices as in (1.3). The wage equation, together with the price expectation equation (1.3), implies that productivity-adjusted wages depend upon past prices, cyclical demand, and supply shocks.

If we substitute the price expectation equation (1.3) into the wage equation (1.2) and the resulting wage equation into the price equation (1.1), we get the traditional reduced-form Phillips curve of the form given in (2).

$$\Delta p_t = a_0 + a_1(L)\Delta p_t + a_2 x_t + a_3 SS_t, \tag{2}$$

where SS represents supply shocks, $a_1\ (L)$ is a lag operator, and other variables are defined as before. The parameters a_i, $i = 0$, 1, 2, in (2) are functions of the parameters in the underlying price and wage equations. Equation (2) says current inflation depends on lagged inflation, cyclical demand, and supply shocks.

The key feature of the Phillips curve (2) is that current inflation does not directly depend on the productivity-adjusted wage once we control for the influences of lagged inflation and the cyclical demand on inflation. This feature rests on the assumption that wages adjust one-for-one with productivity each period, so that the productivity-adjusted wages depend only on lagged inflation and the cyclical demand (as hypothesized in (1.2) and (1.3)). Under this specification, productivity-adjusted wages have no independent influence on inflation once we allow for the influences of lagged inflation and the cyclical demand.

The assumption above—wages adjust one-for-one with productivity each period—may not hold in practice, especially during a period when productivity is undergoing a structural shift. In that case, the productivity-adjusted wage may change due to reasons other than those captured in the wage equation (1.2) and hence may play an independent role in determining inflation in the short run. Thus, an acceleration of productivity growth that is accompanied by anemic wage growth may lead to lower inflation if firms pass through the productivity-induced declines in unit labor costs in lower product prices.

In order to motivate the empirical specification of the influence of productivity on inflation, note first that “the price markup hypothesis” that underlies (1.1) can be summarized in the following price equation:

$$p_t = b_0 + b_w w_t - b_q q_t, \tag{3.1}$$

where all variables are defined as before and the parameters b_w and b_q measure the responses of the price level to nominal wages and productivity, respectively. The price equation (3.1) says the price level declines if nominal wages decline or productivity rises; the magnitude of the price response depends in part on the size of the pertinent wage or productivity response coefficient. The assumption implicit in the inflation specification (1.1) is that the underlying wage and productivity response coefficients are equal in magnitude but opposite in signs, an assumption that may not hold in practice.

If we subtract w_t and add q_t to both sides of the price equation (3.1), we can rewrite the price equation (3.1) as (3.2).

$$p_t - w_t + q_t = b_0 + (b_w - 1)w_t - (b_q - 1)q_t, \tag{3.2}$$

where all variables are defined as before. The left-hand side of the reformulated price equation (3.2) is the markup, defined as the excess of the price level over unit labor costs. Equation (3.2) links the markup $(mrk_t \equiv p_t - (w_t - q_t))$ to the behavior of wages and productivity, given the price level. If we assume prices are sticky in the short run, then the markup will move in response to changes in wages and/or productivity. Since in the long run the price level adjusts to reflect economic fundamentals as envisioned in "the price markup hypothesis," a rise in the markup has implications for the near-term behavior of inflation. Thus, if unit labor costs decline in response to the acceleration of productivity and the markup rises, then the price level should eventually decline to reflect lower unit labor costs, leading to lower inflation down the road. Hence I modify the traditional Phillips curve to include the one-period lagged value of the markup as in (4).

$$\Delta p_t = a_0 + a_1(L)\Delta p_t + a_2 x_t + a_3 SS_t + a_4 mrk_{t-1}. \tag{4}$$

Under the assumption that the "price markup hypothesis" is valid, the expected sign of the coefficient that appears on the markup should be negative, suggesting that the high level of the markup is associated with a decline in the inflation rate. As can be seen, the modified Phillips curve reduces to the traditional Phillips curve if a_4= 0 in (4).

In some previous work analysts have captured the influence of unit labor costs on inflation by including wage share in the Phillips curve (Galí and Gertler 2003). The wage share, however, moves inversely with the markup, and one should obtain similar results using the wage share. Note that the (log of) wage share is just the (log of) real wage per hour minus the (log of) output per hour. Using the notation introduced above, the wage share can be expressed as (5).

$$WS_t = (w_t - p_t) - q_t \equiv -\{p_t - (w_t - q_t)\}, \tag{5}$$

where WS is the log of wage share and other variables are defined as before. Equation (5) shows wage share is just the inverse of the markup. If productivity rises faster than the real wage, wage share declines, and the markup may move up if prices are sticky in the short run. The expected sign of the coefficient on wage share when included in the Phillips curve is positive, implying inflation is predicted to fall if wage share declines. As a robustness check, I shall examine results using the wage share also.

In most previous empirical work, the Phillips curve (2) has been estimated with excess demand measured by the output gap or unemployment gap. I now consider another modification to the Phillips curve, arguing excess demand be measured by the level and change in output gap. The main reason for considering the rate of change specification is that in a reformulated version of this Phillips curve inflation depends explicitly on the excess of the growth rate of aggregate demand over that of potential. This reformulation better captures the potential demand channel consequence of the ongoing acceleration of productivity, emphasized by Kohn (2003). Consider the Phillips curve (4) augmented to include the change in output gap as in (6).[9]

$$\Delta p_t = a_0 a_1(L)\Delta p_t + a_2 y_t + a_3 SS_t - a_4 mrk_{t-1} + a_5 \Delta y_t, \tag{6}$$

where y is now the output gap and where all other variables are defined as before. Following Gordon (1983), I reformulate the inflation equation (6) as follows. Note first that the level of the output gap is linked to the growth rate of nominal GDP via the following identity.

$$y_t \equiv y_{t-1} + (\Delta Y_t - \Delta pot_t) - \Delta p_t, \tag{7}$$

where Y is nominal GDP and pot is real potential output. If we substitute (7) into (6) and rearrange terms, we get the modified Phillips curve (8).

$$\begin{aligned} \Delta p_t \quad = \quad & (1/(a_2 + a_5))[a_1(L)\Delta p_t + (a_2 + a_5)(\Delta Y_t - \Delta pot_t) \\ & + a_2 y_{t-1} + a_3 SS_t + a_4 mrk_{t-1}, \end{aligned} \tag{8}$$

where all variables are defined as before. According to equation (8), among other things, inflation depends on the contemporaneous "demand growth gap"

[9] A theoretical model consistent with a structural Phillips curve—in which current inflation depends also on a change in the output gap—appears in Mankiw and Reis (2001). Under the assumption that information is sticky, they derive a Phillips curve in which inflation depends on the level and change in the output gap, besides depending on past expectations of the current inflation rate.

defined as the excess of the growth rate of nominal aggregate demand over that of real potential output,[10] besides depending on the "level" of the output gap. In this framework, the estimated coefficient on the lagged output gap indicates the presence of an output "level effect," while the difference between the coefficient on the "demand growth gap" and the output gap indicates the relative size of the "rate of change effect." An interesting implication of this Phillips curve is that during the period when there is an outgoing shift in productivity indicating higher real potential output near term, aggregate demand has to grow fast enough to absorb higher potential output. If aggregate demand fails to keep up with higher potential output, disinflationary pressures may develop, even when there may be no slack as measured by the level of the output gap. To illustrate this point further, the most recent estimates of potential output prepared by the Congressional Budget Office indicate real potential output rising at a 3.5 percent annual rate since the mid-1990s. This trend growth rate of 3.5 percent is one percentage point higher than the trend rate for the preceding period of 1990 to 1994. This upward shift in the trend growth rate of real potential implies aggregate demand now has to grow at a higher rate than before, otherwise deflationary pressures will develop.

A Visual Look at Some Data: Demand Growth Gap, Output Gap, Markup, and Wage Share

I estimate the modified Phillips curve (8) using quarterly data from 1959Q1 to 2003Q4. Inflation is measured by the behavior of the chain-weighted GDP deflator. In most previous work, potential output has been estimated fitting a deterministic time trend to real output. I, however, use estimates of potential output prepared by the Congressional Budget Office. I consider two supply shock variables: one associated with change in the relative price of imports and the other arising as a result of the imposition and removal of President Nixon's price controls. The effects of price controls are captured by means of two dummies: PC1 defined to be unity from 1971Q3 to 1972Q4 and zero otherwise, and PC2 defined to be unity from 1973Q1 to 1974Q4 and zero otherwise. The relative import price series is the GDP deflator for imports divided by the implicit GDP deflator. The nominal wage series is compensation per man hour, and the productivity series is output per man hour, both of the nonfarm business sector.[11] The inflation equations are estimated with an instrumental variables procedure. The instruments used are: a constant;

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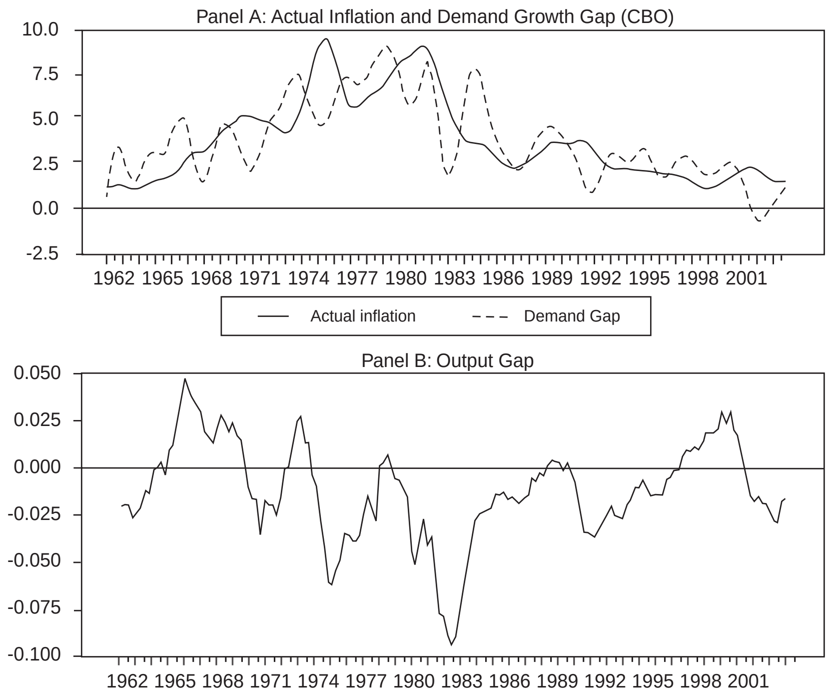
[10] Gordon (1983) calls it "adjusted nominal growth." I think the term "demand growth gap" better captures the way inflation depends on how fast aggregate demand is growing relative to potential supply.

[11] The empirical work here is done using revised, not real-time, data. Hence the conclusions regarding the predictive accuracy of the Phillips curve must be viewed with caution.

Figure 1

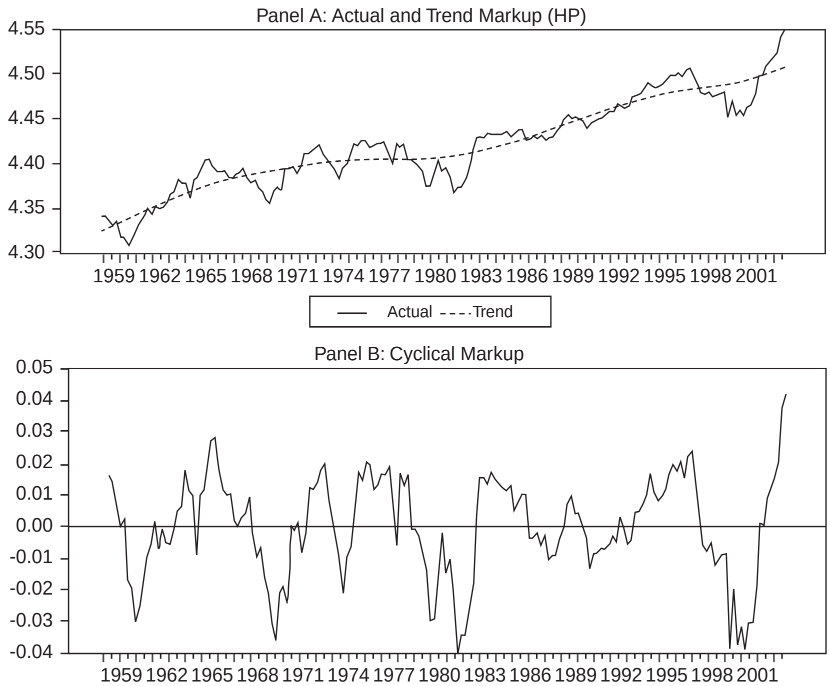


contemporaneous change in military expenditures; and four lagged values of the inflation rate, change in the federal funds rate, gap variables, and change in the relative price of imports.[12]

Figures 1 through 5 provide a visual look at the behavior of some key variables that enter the modified Phillips curve. Panel A of Figure 1 charts the demand growth gap and actual inflation. Both variables measure changes defined over four-quarter periods and are smoothed further by taking the four-quarter moving average of the variables. Figure 1 illustrates that actual inflation and the demand growth gap have moved together over time. Inflation steadily increased in the late 1960s and the 1970s, accompanied by steadily expanding demand growth gap. Similarly, a declining demand growth gap

[12] I do present results of the test that the instruments used are not correlated with the residuals of the estimated Phillips curves. That test is implemented regressing the residuals from the instrumental variables regression on the instruments. See Table 1 (p. 15) which reports the significance levels of the pertinent Chi-square statistic, x^2, defined as T times the R^2 from this regression and distributed Chi-square with (K-1) degrees of freedom, where T is the sample size and K is the number of instruments.

Figure 2

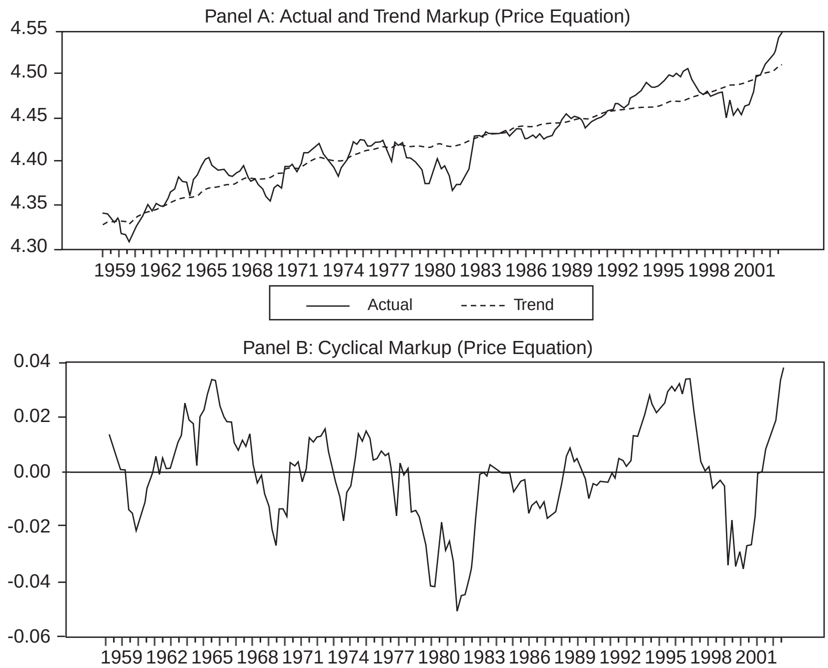


accompanied the steady decline in inflation observed during the 1980s and the 1990s. In particular, during the second half of the 1990s, inflation was stable and so was the demand growth gap. However, for most of the past three years aggregate demand has not kept up with real potential output and hence the resulting decline in the demand growth gap has accompanied the most recent decline in the inflation rate.

Panel B of Figure 1 charts the level of the output gap. The output gap is not smoothed. During the past three years the output gap has been negative and remains so currently, despite last year's upturn in the demand growth gap.

Panel A of Figure 2 charts the markup defined as the excess of the price level over productivity-adjusted wage (markup $= p_t - (w_t - q_t)$). As can be seen, the markup displays a slow-moving trend. I de-trend the markup, using the Hodrick-Prescott (1997) filter. Panel B of Figure 2 charts the cyclical component of the markup. As can be seen, for much of the 1990s the cyclical markup has been positive. Furthermore, in recent quarters the cyclical component has reached levels not seen in the recent past. As of the fourth quarter of 2003, the cyclical component is above 4 percent.

Figure 3

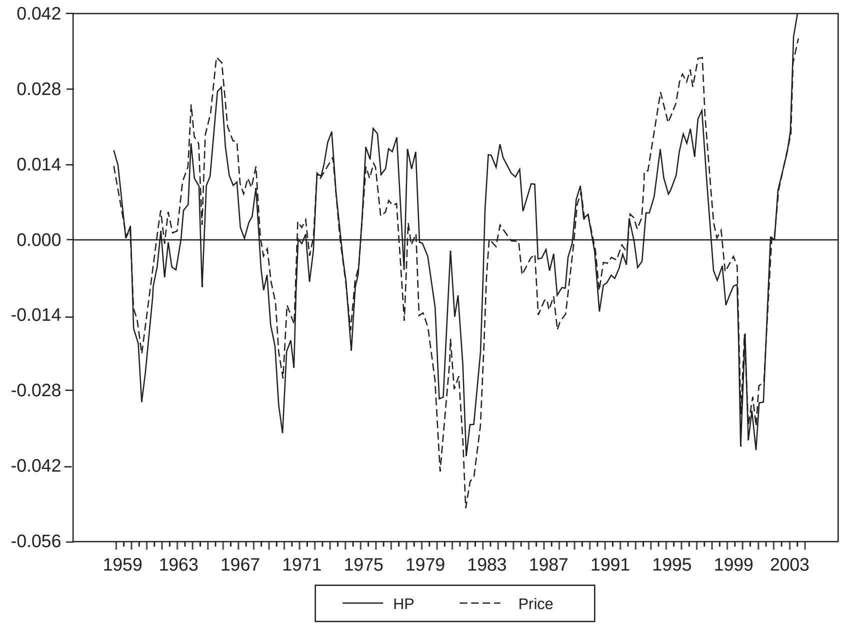


As indicated in Figure 2, the markup series has a slow-moving trend. One simple explanation of the trend in the markup series is suggested by the price equation (3.2), which is that the firms do not pass through part of the productivity-led decline in unit labor costs in lower product prices. In order to explain this point further, note that the markup, as formulated in the price equation (3.2), is constant if the coefficients that appear on wage and productivity variables are unity, as will be the case if there is perfect competition. However, if in practice these coefficients are different from unity, then the markup may have trend if wage and/or productivity series have trend.

In order to explore this source of trend in the markup series, I present below the price equation (3.2), estimated using aggregate data on the price level, nominal wages, and average productivity over the whole sample period 1959Q1 to 2003Q4.

$$p_t - w_t + q_t = 3.1 - \underset{(2.9)}{.04}\, w_t + \underset{(6.7)}{.34}\, q_t + \mu_t. \qquad (9)$$

Figure 4 Cyclical Markup: HP versus Price Equation



As can be seen, the estimated coefficient that appears on the wage variable is not economically different from zero, but the one that appears on the productivity variable is different from zero. Since the productivity variable has a trend, the estimated price equation implies the observed trend in the markup arises because not all of the productivity gain passes through in lower prices.[13]

Panel B in Figure 3 charts the residuals from the estimated price equation (9), which is the measure of the cyclical markup.[14] This measure of the cyclical markup appears similar to the one estimated using the HP filter, as shown in Figure 4. The simple correlation between these two cyclical measures of the markup is 0.84. I consider results with both these measures.

[13] The empirical evidence here that the estimated coefficient on productivity in the price equation is not unity is in line with the evidence in Bils and Chang (2000). Using the U.S. manufacturing data, they estimate industry price equations and find product prices respond weakly to declines in marginal costs driven by increases in labor productivity, suggesting not all of the gain in productivity shows up in the form of lower product prices. They attribute this result to the presence of imperfect competition. It is plausible that similar forces might be at work at the aggregate level.

[14] For generating the cyclical markup I have set the wage response coefficient in the estimated markup equation to zero, thereby implicitly assuming the wage response coefficient in the price equation is unity.

Figure 5 Wage Share

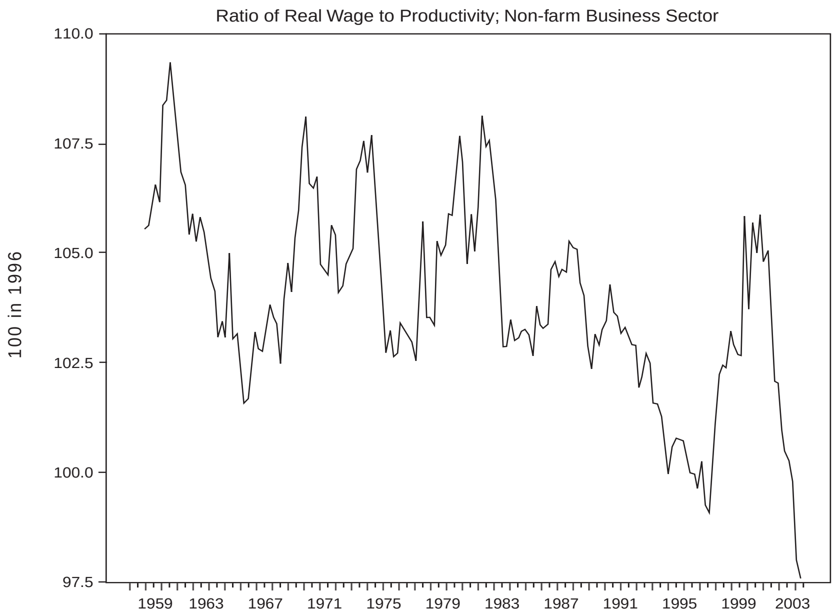


Figure 5 charts the wage share calculated using the nonfarm business sector data on the nominal average hourly compensation, price level, and average productivity. As shown in equation (5), the wage share can be expressed as the ratio of the real wage to the average product of labor.[15] A look at Figure 5 indicates that the wage share series calculated using the nonfarm business sector data does not have as noticeable a trend as the markup series shown in Figure 2. However, the wage share does show a distinct decline in recent years, indicating productivity has grown faster than the real wage. Since in previous research many analysts have used the wage share to explain inflation dynamics, as a robustness check, I also examine results using the wage share.[16]

[15] Wage share is usually calculated as total labor compensation $(W * n)$ divided by total factor income $(p * y)$. One can then express the wage share as the ratio of real wage to the average product of labor, as shown: Wage share $= (W * n) / (P * y) \equiv (W/P)/(y/n) \equiv (W/P)/(q)$, where W is the nominal wage; n is the number of hours; y is real output; P is the price level; and q is the average product of labor. The wage share declines if productivity rises faster than the real wage.

[16] See, for example, Galí and Gertler (2003).

2. EMPIRICAL RESULTS

This section reports and discusses empirical estimates of the modified Phillips curve (8). It also examines whether the estimated Phillips curve predicts the behavior of inflation during the 1980s and the 1990s.

Estimated Phillips Curves

Table 1 reports estimates of the traditional and modified Phillips curves over two sample periods, 1961Q2 to 1995Q4 and 1961Q2 to 2003Q4. The shorter sample period excludes observations pertaining to the most recent subperiod of productivity surge. The estimated coefficients (with t-values in parentheses) reported are those that appear on the demand growth gap, output gap, cyclical markup, lagged inflation, and the relative import price inflation. The coefficient on lagged inflation reported is the sum of coefficients that appear on four lagged values of the inflation rate.

Rows 1 and 2 present estimates of the traditional Phillips curve that relates current inflation to the contemporaneous output gap, lagged inflation, and the relative import price inflation. As can be seen, the estimated coefficients appearing on the output gap, lagged inflation, and import price inflation have positive signs and are statistically significant, suggesting current inflation is positively correlated with the contemporaneous output gap, lagged inflation, and import price inflation. These results hold over both the sample periods.

Rows 3 and 4 present estimates of the modified Phillips curve that allow inflation to depend on the change in the output gap, but not on the markup. As can be seen, the estimated coefficient that appears on the demand growth gap has a positive sign and is statistically significant, meaning inflation is predicted to rise if aggregate demand grows faster than real potential output. The other estimated coefficients that appear on the output gap, lagged inflation, and the relative import price inflation remain correctly signed and significant. The point estimates of the coefficient on the contemporaneous demand growth gap are in a 0.10 to 0.14 range, implying the current quarter predicted increase in inflation following a one percentage point rise in the demand growth gap is 0.10 to 0.14 of a percentage point. These estimates suggest that the cumulative predicted increase in inflation over one year, resulting from a one percentage point sustained increase in the demand growth gap, is about 0.4 to 0.6 of a percentage point.[17]

Rows 5 through 8 present the modified Phillips curve estimated with the demand growth gap and cyclical markup.[18] Rows 5 and 6 present estimates

[17] In Gordon (1983) the estimate of the cumulative increase in inflation over the year resulting from a sustained rise in the demand growth gap is 0.4 of a percentage point, which is near the low end of the range estimated here.

[18] The actual markup, when included in the estimated Phillips curve, is never significant. As can be seen from Figures 1 and 2, the markup series has a slow-moving trend whereas the inflation rate series appears stationary over the whole sample period.

Table 1 Conventional and Modified Reduced-form Phillips Curves GDP Inflation

Row No.	End Period	Output Gap (d_1)	Demand Growth Gap (d_2)	Cyclical Markup (d_3)	Lagged Inflation (d_4)	Import Prices (d_5)	R^2	x^2
1	1995Q4	0.03			00.90	0.07	0.84	0.80
		(2.90)			(21.30)	(4.60)		
2	2003Q4	0.03			00.91	0.06	0.86	0.67
		(3.10)			(24.20)	(5.20)		
3	1995Q4	0.03	0.10		00.85	0.07	0.86	0.84
		(3.50)	(2.10)		(20.30)	(5.30)		
4	2003Q4	0.03	0.10		00.86	0.07	0.87	0.72
		(3.70)	(2.10)		(22.20)	(5.30)		
5	1995Q4	0.04	0.14	−0.03	00.82	0.06	0.86	0.42
		(3.90)	(2.80)	(1.90)	(18.90)	(4.50)		
6	2003Q4	0.03	0.11	−0.02	00.85	0.06	0.87	0.47
		(3.90)	(2.30)	(1.20)	(20.70)	(5.30)		
7	1995Q4	0.05	0.13	−0.05	00.78	0.06	0.87	0.53
		(3.10)	(2.80)	(1.90)	(18.90)	(4.60)		
8	2003Q4	0.04	0.11	−0.03	00.83	0.06	0.88	0.48
		(2.10)	(2.40)	(2.10)	(19.40)	(5.30)		
9	1995Q4	0.04	0.14	0.02	00.81	0.06	0.86	0.63
		(4.20)	(3.40)	(1.70)	(19.40)	(4.60)		
10	2003Q4	0.04	0.12	0.02	00.83	0.06	0.87	0.78
		(4.40)	(3.20)	(1.70)	(20.80)	(5.20)		

Notes: With the exception of the coefficients in rows 9 and 10, the estimated coefficients (with t-values in parentheses) are from reduced-form Phillips curves of the form $\Delta p_t = d_0 + d_1 y_{t-1} + d_2(\Delta Y_t - \Delta pot_t) + d_3 mrk_{t-1} + d_4 \Delta p_{t-1} + d_5 SS_t$, where all variables are in their natural logs and where p is the price level; Y is nominal GDP; pot is real potential output; y is the output gap; $(\Delta Y_t - \Delta pot_t)$ is demand growth gap; and SS is relative import prices. The coefficients reported in rows 9 and 10 are from Phillips curves, estimated using wage share instead of the markup. The reported coefficient on lagged inflation is the sum of the estimated coefficient on its four lagged values. The inflation equations are estimated over the sample periods that all begin in 1961Q2 but end as shown above, using an instrumental variables procedure. The instruments are: a constant; four lagged values of the inflation rate, output gap variables, changes in the federal funds rate, and relative import prices; and change in the current nominal defense expenditure. The estimated inflation equations also included the Nixon price control dummies. The significance level of the test that the instruments are not correlated with the residuals of the Phillips curve is x^2.

generated using the cyclical markup based on the HP filter, and rows 7 and 8 present estimates with the cyclical markup generated using the estimated price equation. The estimated coefficient that appears on the markup has a negative sign and is significant, especially over the shorter sample period, meaning inflation is predicted to decline if the markup is high. In the longer sample period, the markup—though it continues to appear with a correctly signed estimated coefficient—is not significant if the Phillips curve is estimated using the cyclical markup based on the HP filter.[19]

The point estimates of the coefficient that appears on the cyclical markup fall in a –0.02 to –0.05 range, suggesting that in response to a one percentage point increase in the markup, the cumulative predicted decline in the inflation rate over the year is about 0.10 to 0.20 of a percentage point, which is not large in magnitude. Moreover, augmenting the Phillips curve to include the cyclical markup does not much improve the explanatory power of the inflation regression, as measured by the R-squared statistic. (Compare estimates in rows 3 and 4 with those in rows 5 through 8, Table 1).[20] Despite these caveats, the estimated Phillips curve with the markup is capable of generating the prediction of a significant fall in the inflation rate during periods of high cyclical markups, which may be periods when productivity is accelerating but wage growth remains anemic.[21]

Rows 9 and 10 present estimates of the coefficients from the modified Phillips curve that includes the wage share rather than the markup. The estimated coefficient on the wage share is positive, suggesting that inflation is predicted to decline if the wage share declines. The size of the estimated coefficient on the wage share appears to be of the magnitude found using the cyclical markup. All the remaining variables appear with correctly signed estimated coefficients and are significant in the estimated Phillips curve.

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[19] The serial correlation coefficients estimated using the residuals series from the estimated modified Phillips curve are small, indicating serial correlation is not a problem. The significance level of the Chi-squared test of the null hypothesis that instruments are uncorrelated with the residuals (reported in Table 1) indicates that the null is not rejected.

[20] In fact, the explanatory power of the regressions as measured by the R-squared statistic does not improve much if demand growth gap and markup variables are added into the traditional Phillips curve. However, these two variables significantly enter the modified Phillips curve. The significance level of the F statistic, testing the null hypothesis that the estimated coefficients on these two variables are zero, falls in a 0.00 to 0.03 range and leads to the rejection of the null. Together these results, however, do imply that the quantitative contribution of these two variables in predicting inflation may not be large, as we see later.

[21] In some previous research the potential influence of unit labor costs on inflation has been investigated, using cointegration and error correction methodology (Mehra 1991, 1993, 2000). In particular, the influence of unit labor costs on inflation is investigated in two steps. In step one, the cointegrating (long-run) relationship between the price level and unit labor costs is investigated, resulting in an estimated price equation like (3.1) in which wage and productivity response coefficients are assumed to be opposite in sign but equal in magnitude. The residual series from the estimated price equation is the error-correction variable, which measures the gap between the actual price level and the price based on unit labor costs—a variable similar in spirit to the cyclical markup used here. In the second step, the inflation equation is estimated including, among other variables, the lagged value of the error-correction variable. In previous research the error-correction variable is generally found to be insignificant, suggesting unit labor costs have no direct influence on inflation (Gordon 1988; Mehra 1993, 2000). The new empirical evidence here indicates that the error-correction variable estimated without imposing unitary coefficient restrictions on the price equation is somewhat more favorable to the view that productivity-led declines in unit labor costs may matter for the short-term behavior of inflation.

Predicting the Behavior of Inflation During the 1980s and the 1990s: Are Phillips Curves Useful?

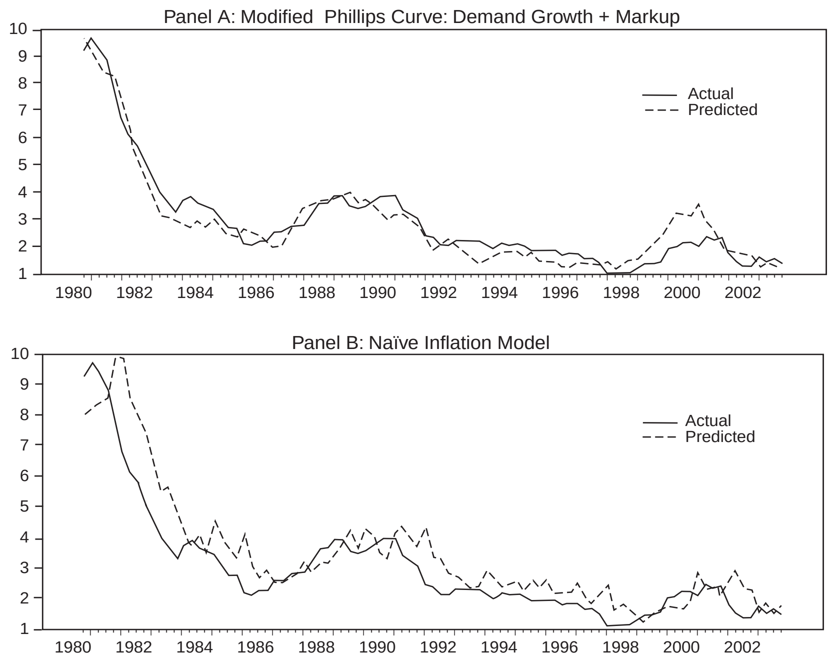
Panel A in Figure 6 charts the dynamic, one-year-ahead predictions of the inflation rate generated using the rolling regression estimates of the modified Phillips curve with the markup over the period 1980–2003.[22] As indicated before, these predictions are conditional on actual values of the explanatory variables suggested by the Phillips curve. Panel B charts the dynamic predictions of the inflation rate generated using a naïve model that predicts inflation using only four lagged values of the inflation rate. Actual inflation rates are also charted there. As can be seen, the estimated modified Phillips curve tracks actual inflation fairly well. The naïve model, however, tends to overpredict inflation, first during the early 1980s and then in the second half of the 1990s.

Table 2 presents the statistical evidence on the relative accuracy of inflation predictions. It presents the mean error (ME) and the root mean squared error (RMSE) of the prediction from several different Phillips curves including the one in which the unemployment rate, not the output gap, is the main activity variable as in Atkeson and Ohanian (2001). The predictive accuracy is evaluated over 1980–2003 as well as over the period 1984–1999 covered in Atkeson and Ohanian. The relative accuracy is evaluated by computing the ratio of the RMSE of the prediction from a given Phillips curve with the RMSE of the naïve model's prediction. The naïve inflation model is said to generate more accurate predictions of inflation than a given Phillips curve if the ratio is above unity. The Phillips curves considered here are: the traditional Phillips curve that relates current inflation to the contemporaneous output gap, lagged inflation, and supply shocks; the traditional Phillips curve augmented to include demand growth gap; the traditional Phillips curve augmented to include both demand growth gap and markup or wage share; the traditional Phillips curve augmented to include just the wage share; and the NAIRU Phillips curve that relates current inflation to four lagged values of the unemployment rate and the inflation rate.

If we focus on estimates of the ratio reported for the sample period 1980–2003, we see that the ratio is less than unity for all the Phillips curves considered here. The point estimates of the ratio fall in a 0.5 to 0.9 range, suggesting the Phillips curves considered here provide more accurate predictions of the inflation rate than does the naïve model. The ratio estimated using predictions from the traditional output gap-based Phillips curve or the modified Phillips curve with demand growth gap is close to 0.5, far below unity. The results also

[22] The estimation periods that underlie the rolling regressions all begin in 1961Q1 but end in the year before the forecast period. Thus the Phillips curve is first estimated over 1961Q1 to 1979Q4 and then dynamically simulated over 1980Q1 to 1980Q4 to generate the one-year-ahead prediction of the inflation rate for 1980. The end of the estimation period is then advanced one quarter, the Phillips curve re-estimated and dynamically simulated to generate the one-year-ahead prediction of the inflation rate, and so on.

Figure 6 Actual and Predicted Inflation: 1980–2003



indicate the markup or wage share does not aid much in improving the RMSE of the prediction as do the output gap and supply shock variables (compare RMSEs across models in Table 2).

If we focus on estimates of the ratio for the period 1984–1999, they suggest qualitatively similar inferences about the relative predictive accuracy of the Phillips curve and the naïve model. The prediction of inflation from the modified Phillips curve with demand growth gap has the lowest RMSE, outperforming the naïve model's prediction by a substantial margin. The ratio of the RMSEs for these two models is 0.56 (see Table 2). In contrast, the ratio of the NAIRU Phillips curve and naïve models' RMSEs is 0.88, not too far below unity, suggesting the NAIRU Phillips curve does not aid much in improving accuracy relative to the naïve model.[23] Together these results suggest Phillips curves are useful for predicting inflation.

[23] The relative poor accuracy of the NAIRU Phillips curve may be due to the use of the unemployment rate rather than the unemployment gap, implicitly assuming a constant NAIRU over the sample period.

Table 2 Test of Relative Predictive Accuracy

Panel A: Sample Period 1980–2003

Model	ME	RMSE	RATIO
Naïve	−0.48	0.91	
Traditional Phillips Curve	−0.10	0.53	0.56
Traditional Phillips Curve			
+ Demand Growth Gap	−0.00	0.48	0.53
+ Demand Growth Gap + Markup	0.05	0.51	0.56
+ Demand Growth Gap + Wage Share	0.20	0.52	0.57
+ Wage Share	0.03	0.55	0.62
NAIRU Phillips Curve	−0.20	0.80	0.88

Panel B: Sample Period 1984–1999

Model	ME	RMSE	RATIO
Naïve	−0.41	0.66	
Traditional Phillips Curve	−0.21	0.43	0.65
Traditional Phillips Curve			
+ Demand Growth Gap	−0.13	0.37	0.56
+ Demand Growth Gap + Markup	−0.10	0.42	0.64
+ Demand Growth Gap + Wage Share	0.13	0.40	0.60
+ Wage Share	0.04	0.38	0.65
NAIRU Phillips Curve	−0.25	0.58	0.88

Notes: ME is mean prediction error; RMSE is the root mean squared error; and RATIO is the ratio of Phillips Model/Naïve Model RMSEs. The traditional Phillips curve relates current inflation to contemporaneous output gap, lagged inflation, and supply shocks. The NAIRU Phillips curve relates current inflation to four lags of inflation and unemployment rate. The prediction of inflation used is the dynamic, one-year-ahead predicted inflation rate generated using the Phillips curve model and conditional on actual values of other explanatory variables. If the RATIO is below unity for a Phillips curve model, it implies the Phillips curve model generates more accurate predictions of the inflation rate than does the Naïve model.

Predicting the Behavior of Inflation since the Mid-1990s

Table 3 focuses on the behavior of inflation since the mid-1990s. The column labeled (2) presents the inflation predictions generated using the traditional output gap-based Phillips curve and estimates of potential output prepared by the Congressional Budget Office. As can be seen, the traditional Phillips curve still tends to overestimate inflation somewhat. The bias measured by the mean

Table 3 Actual Predicted Inflation 1995–2003

Year	Act.	Pred.	Pred.	Pred.	Pred.	DGG	OG	mrk
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1995	1.90	2.50	2.30	1.50	1.70	1.10	−1.30	3.10
1996	1.80	1.90	1.90	1.30	1.50	3.10	−0.10	3.60
1997	1.50	1.90	1.90	1.40	1.50	2.40	0.90	2.30
1998	1.10	1.50	1.40	1.60	1.30	2.10	1.90	0.00
1999	1.50	2.00	1.90	2.50	2.00	2.60	3.00	−0.70
2000	2.20	2.70	2.50	3.30	2.70	**0.90**	1.70	−3.10
2001	2.40	2.10	1.70	2.20	1.80	**−1.00**	−1.70	−1.70
2002	1.40	2.00	1.80	1.80	1.60	**0.70**	−2.40	1.60
2003	1.50	1.70	1.60	1.30	1.20	2.30	−1.50	4.00
ME		−0.33	−0.21	−0.22	−0.04			
RMSE		0.42	0.35	0.56	0.35			

Notes: The predicted values are the dynamic, one-year ahead forecasts of the GDP inflation rate (4Q to 4Q) generated using rolling regression estimates of the modified Phillips curve reported in Table 1. The forecasts are conditional on actual values of nominal GDP growth, potential output, wage growth, productivity growth, and import prices. **Act.** is actual inflation; **Pred.** is the predicted inflation rate, **DGG** is demand growth gap; **OG** is the output gap; **mrk** is the cyclical markup (price equation); **ME** is the mean prediction error; and **RMSE** is the root mean squared error.

The predicted values given in column (2) are from the traditional Phillips curve; those given in column (3) are from the Phillips curve augmented to include demand growth gap; those given in column (4) are from the Phillips curve augmented to include demand growth gap plus the markup; and those in column (5) are from the Phillips curve augmented to include demand growth gap plus the wage share.

prediction error is -0.33, one-third of a percentage point, and the root mean squared error is 0.44.[24]

The inflation predictions generated using the modified Phillips curve are presented in the columns labeled (3), (4), and (5). The predictions in column (3) are from the Phillips curve with the demand growth gap, those in column (4) are from the Phillips curve with the demand growth gap and markup, and those in column (5) are from the Phillips curve with the demand growth gap and wage share. Augmenting the Phillips curve to include the demand growth gap does improve the predictive accuracy. The Phillips curve with the demand

[24] Note that the prediction bias is larger in magnitude if one does not allow for productivity-led increases in potential real output since the mid-1990s. Under the counterfactual assumption that real potential output continues to increase at its earlier trend growth rate of 2.5 percent since the mid-1990s, the inflation rates predicted using the traditional Phillips curve for the years 2000, 2001, 2002, and 2003 are 3.0, 2.5, 2.6, and 2.4 percent, respectively. The mean prediction error is -0.67 of a percentage point, and the RMSE is 0.74.

growth gap has a lower mean error and lower root mean squared error than the Phillips curve without the demand growth gap. But further augmenting the Phillips curve to include the cyclical markup or wage share does not aid much in improving the predictive accuracy of the long-range inflation forecasts.

Table 3 also presents the underlying data on the demand growth gap, output gap, and cyclical markup over the period since the mid-1990s. Regarding sources of the recent deceleration of inflation, the correlations summarized in the estimated modified Phillips curve suggest one plausible explanation of the recent behavior of inflation.[25] As can be seen in Table 3, inflation, after hovering mostly near a low of 2 percent in the second half of the 1990s, decelerated further during the past three years. In the second half of the 1990s, the demand growth gap stayed close to the 2 percent range as aggregate demand grew just fast enough to absorb the productivity-induced increase in potential. However, during the most recent period, 2000–2002, aggregate demand did not grow fast enough to absorb higher potential, creating a declining demand growth gap and a negative output gap. The recent deceleration is well predicted by the behavior of the Phillips curve that includes these two gap variables. However, the contribution of the markup (or wage share) in improving the prediction of the inflation rate since the mid-1990s remains negligible, suggesting the markup is not providing information beyond that contained in the gap variables. Together these results suggest a weak demand growth gap together with the resulting negative output gap, trumping the cyclical markup (or wage share) as the major source of the recent deceleration of inflation.

Generating a Conditional Prediction of the Inflation Rate for 2004

What do the Phillips curves estimated here imply about the behavior of inflation during 2004? In order to answer this question, I generate the conditional prediction of the inflation rate for 2004. During the past two years productivity has increased at an average annual rate of 4.5 percent, whereas nominal wages have increased at an average annual rate of 2.4 percent, implying an average annual decline of 2.5 percent in unit labor costs. Aggregate demand, as measured by nominal GDP, has grown at an average annual rate of 5 percent. Potential output, as estimated by the Congressional Budget Office, has grown at a 3.5 percent annual rate. If productivity, wages, aggregate demand, and potential output continue to grow in 2004 at rates observed during the past two years, the point estimate of the conditional prediction of inflation for 2004, generated using the Phillips curve with demand growth gap and markup, is

[25] There may be other structural models that are consistent with the correlations summarized in the modified Phillips curve. Hence one may come up with other explanations of the recent behavior of inflation.

1.0 percent. The conditional prediction of the inflation rate is 1.5 percent if the modified Phillips curve excludes the markup. Last year the GDP deflator grew 1.5 percent. The ensuing behavior of inflation this year would provide further evidence on the predictive accuracy of the Phillips curve that includes the markup.

3. CONCLUDING OBSERVATIONS

This article makes two modifications to the traditional output gap-based Phillips curve. It includes the cyclical component of a markup variable defined as the markup of prices over unit labor costs, and it allows inflation to depend also on a change in the output gap. The markup allows for the short-term influence of productivity-induced decline in unit labor costs on inflation, and the "rate of change" specification implies inflation depends also on how fast aggregate demand is growing relative to real potential output. The results indicate demand growth gap and the level of the cyclical markup enter the traditional Phillips curve with significant and correctly signed estimated coefficients. Inflation is predicted to increase if aggregate demand grows faster than real potential output, and it is predicted to fall if the markup is high.

The predictions of the one-year-ahead inflation rate conditional on actual values of the explanatory variables suggested by the traditional and modified output gap-based Phillips curves track actual inflation well over 1980–2003, outperforming those based on a naïve model that predicts inflation using only lagged inflation. These results imply output gap-based Phillips curves are useful in predicting inflation.

As a result of the recent acceleration of productivity, the trend growth rate of real potential output has increased since the mid-1990s. This upward shift in the trend growth rate of potential output implies aggregate demand needs to grow at higher rates than before in order to stabilize inflation. Inflation remained low in the second half of the 1990s and decelerated further during the past three years. This deceleration of inflation is well predicted by the modified Phillips curve that assigns a key role to demand growth and the output gap. The demand growth gap remained stable in the 2 percent range in the second half of the 1990s, but it declined considerably over the period 2000–2002, creating a negative output gap over the recent period. The negative predicted effect of these two gap variables on the inflation rate trumps the cyclical markup as the major source of the recent deceleration of inflation.

The cyclical component of the markup or the wage share, when added into the traditional and modified Phillips curves, appears with a correctly signed negative estimated coefficient and is generally significant. However, in the past the markup or wage share has not helped in improving the accuracy of the long-range inflation prediction if the estimated Phillips curve includes demand growth and output gap variables. This may be due to the fact that the markup or wage share is also influenced by cyclical demand, besides productivity, and hence is highly correlated with the cyclical measures of excess demand. So, the marginal predictive content of the markup or wage share is small once we control for the influence of cyclical demand on inflation.

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