How Do Central Banks Control Inflation?

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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.

$$MNPS_m - \pi^* = r_B + MNPS_B - \pi^* = r_K + MNPS_K \tag{1}$$

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

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.

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

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.

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[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

[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.

[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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