A New Measure of Monetary Shocks: Derivation and Implications

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This paper develops a measure of U.S. monetary policy shocks for the period 1969–1996 that is relatively free of endogenous and anticipatory movements. Quantitative and narrative records are used to infer the Federal Reserve's intentions for the federal funds rate around FOMC meetings. This series is regressed on the Federal Reserve's internal forecasts to derive a measure free of systematic responses to information about future developments. Estimates using the new measure indicate that policy has large, relatively rapid, and statistically significant effects on both output and inflation. The effects are substantially stronger and quicker than those obtained using conventional indicators. (*JEL* E52, E58, E32, E31)

The accuracy of estimates of the effects of monetary policy depends crucially on the validity of the measure of monetary policy that is used. Use of an inappropriate measure may obscure a relationship between monetary policy and other economic variables that actually exists, or create the appearance of a relationship where there is no true causal link. For this reason, this paper derives a new measure of monetary policy shocks that is free from some key deficiencies of previous measures. The new measure yields estimates of the impact of monetary policy on both real and nominal variables that are stronger and faster than those obtained using conventional indicators.

Conventional measures of monetary policy have some obvious flaws. One is the likelihood of endogenous movements. The money supply, for example, tends to rise in good times because the money multiplier rises. Even the federal funds rate, which has become the standard indicator of monetary actions in studies of the effects of monetary policy, moves a great deal from day to day for reasons unrelated to monetary policy. And, in eras when the Federal Reserve targeted the funds rate less closely than it has in the Greenspan era, the funds rate often moved endogenously with changes in economic conditions. Such endogenous movements may lead to biased estimates of the effects of monetary policy. For example, the tendency of the funds rate to rise endogenously with economic activity may cause researchers to underestimate the negative impact of increases in interest rates on real economic variables.

Another problem with conventional measures is that they almost surely contain anticipatory movements. To avoid the problem of endogeneity, one might use as the measure of policy the Federal Reserve's target for some variable, such as the funds rate or nonborrowed reserves. However, movements in such target series are surely not random. The Federal Reserve invests a huge amount of resources in forecasting the likely behavior of output and prices. As a result, movements in its target series are often responses to information about future economic developments. For example, the Federal Reserve typically cuts the target funds rate if it sees signs that a recession is likely. In such a situation, output is unlikely to rise in the wake of the interest rate cut even if the monetary policy action is having a stimulative effect. If anticipatory countercyclical actions are common, a regression may again fail to find a

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negative relationship between increases in interest rates and output growth even if it is actually present.

To address these difficulties, in this paper we derive a new indicator of monetary policy shocks that avoids the problems in conventional indicators. We begin by deriving a series on intended funds rate changes around meetings of the Federal Open Market Committee (FOMC) for the entire period 1969–1996. To do this we combine information on the Federal Reserve's expected funds rate derived from the *Weekly Report of the Manager of Open Market Operations* with detailed readings of the Federal Reserve's narrative accounts of each FOMC meeting. We find that even for periods when the FOMC did not set an explicit funds rate target, the discussion of policy intentions gives a good indication of desired changes in the funds rate. The resulting series on intended funds rate movements around FOMC meetings eliminates much of the endogenous relationship between interest rates and economic conditions and covers some crucial episodes missed by existing series for the funds rate target, such as the Burns expansion of the early 1970's and the Volcker disinflation of the early 1980's.

We then use the Federal Reserve's internal forecasts of inflation and real activity to purge the intended funds rate of monetary policy actions taken in response to information about future economic developments. These forecasts, commonly referred to as the "Greenbook" forecasts, are prepared by the Federal Reserve staff before each meeting of the FOMC and play a key role in policy deliberations. We regress the change in the intended funds rate around forecast dates on these forecasts. The residuals from this regression show changes in the intended funds rate not taken in response to information about future economic developments. The resulting series for monetary shocks should be relatively free of both endogenous and anticipatory actions.

We employ our new measure to analyze the responses of output and inflation to monetary developments. We estimate straightforward regressions of the growth rates of industrial production and the producer price index for finished goods on the new measure of monetary shocks. We also estimate similar regressions using the change in the actual funds rate and other broader measures of monetary policy. Such comparisons can show whether using the new measure yields different results than those based on more conventional measures.

The response of industrial production to our measure of monetary shocks indicates a strong relationship. Industrial production begins to fall five months after a contractionary shock and reaches its minimum after roughly two years. The effects are both large and statistically significant. A one-percentage-point realization of our series (which is a substantial, but not exceptionally large movement) is associated with a reduction in industrial production of 4.3 percent.

The same regression run using the change in the actual funds rate as the measure of monetary policy indicates a considerably weaker correlation between monetary developments and real activity. The estimated impact of this broader measure is smaller, slower, and less significant than the impact of our new indicator. This suggests that the endogenous behavior of the funds rate and the anticipatory component of Federal Reserve actions may be substantial, and may obscure some of the true relationship between monetary policy and the real economy.

Our estimates derived using the new measure of monetary shocks also show a strong, if somewhat delayed, negative response of inflation to monetary contraction. We find that in response to a one-percentage-point shock, the price level is virtually unchanged for the first 22 months and then falls steadily relative to what it otherwise would have been. After 48 months the price level is 6 percent lower. The effect is highly statistically significant.

Using the change in the actual funds rate as the measure of monetary policy yields very different results. In our baseline specification, the estimated impact of a rise in the funds rate on the price level is positive for all 48 months that we consider. That is, there is a strong "price puzzle," similar to the positive correlation between monetary tightening and the price level found in the VAR literature (see, for example, Christopher A. Sims, 1992). Thus, again it appears that endogenous movements in interest rates and anticipatory policy moves are obscuring the true effects of monetary policy.

Previous work has found that controlling for commodity prices eliminates the price puzzle when broader measures of policy are used (see, for example, Sims, 1992; Lawrence J. Christiano et al., 1996; Ben S. Bernanke and Ilian Mihov, 1998). Nonetheless, commodity prices may fail to capture important parts of the Federal Reserve's information about future developments. To investigate this issue, we examine the effects of controlling for commodity prices both in regressions estimated using our new measure of monetary shocks and in ones estimated using the broader measures. Controlling for commodity prices has no consistent effect on the impact of policy estimated using our new measure, suggesting that our measure is largely free of anticipatory policy actions motivated by supply shocks. With the broader measures, controlling for commodity prices mitigates the price puzzle. However, the effects of monetary policy actions are still much slower and weaker than when our new measure is used. This suggests that using conventional policy measures but controlling for commodity prices is not enough to deal with endogeneity and forward-looking Federal Reserve behavior.

Most of the recent literature on the effects of monetary policy has used vector autoregressions. To facilitate comparisons with this literature, we run VARs using both our new measure of monetary shocks and the actual federal funds rate. We find that the VAR results using our new measure show a somewhat stronger effect of monetary policy on output and a substantially stronger and more rapid effect on prices than found in the literature or in our VARs using the actual funds rate. This again suggests that endogenous and anticipatory movements may have led to underestimates of the effects of monetary policy.[1]

I. Derivation of a New Measure of Monetary Policy Shocks

The derivation of our new measure of monetary policy shocks has two key steps. The first is to derive a series for Federal Reserve intentions for the federal funds rate around FOMC meetings. The second is to control for Federal Reserve forecasts, and so create a measure of intended monetary policy actions not driven by information about future economic developments.

A. *Changes in the Intended Federal Funds Rate around FOMC Meetings*

Motivation.—The Greenbook forecasts are only done before FOMC meetings. Therefore, the only policy actions for which we can use the forecasts as a proxy for policy makers' information are those around FOMC meetings. Policy actions taken between meetings are often substantial and are usually based on the arrival of new information. As a result, the Greenbook forecast for the previous meeting would likely be a poor indicator of the information that led to the intermeeting action. For this reason, we derive a series for Federal Reserve intentions around FOMC meetings. Concretely, we view the FOMC decisions for which the Greenbook forecasts are a good summary of the Federal Reserve's information to be those from the forecast through the associated FOMC meeting.

The particular variable for which we analyze the Federal Reserve's intentions is the nominal federal funds rate. We focus on intentions for the funds rate, instead of intentions for reserves or other variables, for several reasons. Most obviously, for much of the period for which we have detailed forecast data (1969–1996), the Federal Reserve explicitly targeted the funds rate. This was the case between 1974 and

[1] Several recent investigations of the effects of monetary policy also control for central bank forecasts. Jean Boivin (2001) and Marvin J. Barth III and Valerie A. Ramey (2002) add information from the Federal Reserve's forecasts to largely conventional models of monetary policy and its effects. Per Jansson and Anders Vredin (2001) consider Swedish monetary policy over the period 1992–1998. They include forecast information in their monetary policy reaction function to attempt to isolate policy shocks, and compare the central bank's forecasts with alternatives to attempt to determine the impact of judgmental forecasting on policy. Our paper differs from these studies in two critical respects. First, we derive a genuine measure of policy intentions rather than use the actual interest rate. Furthermore, our measure of policy intentions is derived so that the policy actions occur at the same time as the forecasts. This ensures that the forecasts capture policy makers' anticipations at the time the policy decisions are made. Second, our focus is explicitly on the usefulness of the new measure of monetary shocks that we derive. By comparing the results using the new measure with those using conventional measures, we can see if using a consistent measure of policy intentions and controlling for anticipatory actions affects the estimates of the impact of monetary policy.

September 1979 and for the entire period since the mid-1980's. Therefore, the change in the intended funds rate is the single indicator that best captures what the Federal Reserve was aiming to do over this period.

Even in periods when the FOMC was not explicitly targeting the federal funds rate, it was concerned about this key interest rate and discussed the likely implications of policy actions for its behavior. Therefore, as a practical matter, the change in the intended funds rate is the easiest indicator of Federal Reserve intentions to deduce accurately over a long period of time and over a variety of monetary regimes.

The final reason for focusing on the intended funds rate as the indicator of Federal Reserve intentions is that an interest rate measure is more likely to be consistent over time than other candidates. The same Federal Reserve objectives for quantity variables such as reserves or monetary aggregates may reflect very different intentions even in nearby periods because of regulatory or definitional changes. This is much less likely to be true of the funds rate.

Sources.—To identify changes in the intended funds rate decided upon around FOMC meetings, we use two types of sources. One is the narrative record of FOMC meetings. We use both the published summaries of FOMC discussions contained in the *Record of Policy Actions of the Federal Open Market Committee* and the more complete accounts contained in the *Minutes of Federal Open Market Committee* and, later, the *Transcripts of Federal Open Market Committee.*[2] We also use the FOMC document *Monetary Policy Alternatives,* or the "Bluebook," that is prepared for each FOMC meeting. The Bluebook typically includes a summary of the implementation of policy since the previous meeting and a presentation of some possible decisions for the FOMC.

Our other type of source is more quantitative. Specifically, we employ a pair of internal memos from the Federal Reserve showing the "expected federal funds rate." One covers the period from January 1971 to December 1984 and the other covers the period from December 1983 to September 1992.[3] These memos are based on the *Weekly Report of the Manager of Open Market Operations.* In addition to numerical values, the memos contain brief remarks about the timing of moves and where, within a given range, the open market desk was aiming. These remarks make it clear that the series reflects Federal Reserve intentions rather than passive expectations or forecasts. And indeed, the reported expected federal funds rates are very similar to the target values given in Glenn D. Rudebusch (1995) for the periods when the series overlap (1974–1979 and 1984–1992). The obvious benefit of the internal memos for our purposes is that they also include expected funds rate changes in the early 1970's and the Volcker period.

While the expected funds rate series is a useful input to our identification of Federal Reserve intentions, it is important to note that we do not use it in a mechanical fashion. For example, we do not take the change in the expected rate between the day before the forecast and some arbitrary number of days after the corresponding FOMC meeting. The reason for this is that we only want changes in the expected funds rate for which the forecasts are a reasonable summary of the available information. Some funds rate changes even very soon after FOMC meetings are based on new information, while other funds rate changes two or more weeks after an FOMC meeting are explicitly decided upon at the meeting. For this reason, it is crucial to combine the narrative and quantitative evidence.[4]

[2] The *Minutes* cover the period through March 1976, and the *Transcripts* cover the period beginning in February 1981; no detailed accounts are currently available for the intervening period. The *Record of Policy Actions of the Federal Open Market Committee* is published in the *Annual Report of the Board of Governors of the Federal Reserve System.* These brief summaries were renamed the *Minutes of Federal Open Market Committee Meetings* in 1993. To prevent confusion between the modern, brief *Minutes* and the very detailed *Minutes* for the pre-1976 period, we call the brief summaries the *Record of Policy Actions* in all periods.

[3] We also have an internal e-mail showing the "intended federal funds rate" from March 1984 to the present, which we use as a check on our analysis after September 1992. Since the Federal Reserve has been targeting the funds rate so closely and explicitly since 1987, this check is of little importance.

[4] In addition, a mechanical rule based on the expected funds rate series would not be practical. There are a number

Method.—To derive the intended series, we need to identify the level of the federal funds rate the FOMC intended to prevail at the time of the forecast, and the level it intended on the basis of its decision at its meeting. The *Record of Policy Actions* almost always reports the actual level of the funds rate before the meeting and indicates if it was temporarily deviating from what the Federal Reserve was intending. Thus, it is usually straightforward to deduce the level the FOMC was intending before the meeting. The *Record of Policy Actions* also typically reports any actions taken in the days just before the meeting that might have affected the funds rate, so it is possible to deduce the intended funds rate at the time of the forecast.

We check our preliminary estimate against the expected funds rate from the internal memos. If there is a discrepancy or ambiguity, we examine the more detailed accounts of the meetings in the *Minutes* or *Transcripts* and the descriptions of how policy was implemented in the Bluebooks. If there are discrepancies on these relatively factual issues, we typically resolve them in favor of the expected rate, unless the narrative sources are very explicit. This is especially true of changes between the forecast and the meeting, for which the narrative accounts are often not particularly quantitative.

We also read the *Record of Policy Actions* to see what the FOMC decided to do at the meeting. That is, we determine as well as possible from the narrative description what the FOMC intended to happen to the funds rate as a result of the actions agreed upon at the meeting. This postmeeting level for the intended funds rate incorporates any actions taken between the forecast and the meeting that are confirmed by the FOMC. In deducing the new intended level we make no adjustment for timing: changes that are scheduled to be implemented gradually are treated as immediate changes in intentions.

The *Record of Policy Actions* is often very clear about the change in the intended funds rate. But for some meetings, the FOMC's intentions for the funds rate are more opaque. While this is especially true in the early Volcker era of nonborrowed reserve targeting, it also occurs periodically in eras of quite obvious funds rate targeting. A decision for no change is usually very explicit and the direction of change, if there is one, is usually clear. But the magnitude of the change is often much less explicit.

As with the initial intended rate, we also consider the evidence from the expected funds rate series. Whenever the *Record of Policy Actions* and the expected rate do not yield a clear and consistent view of what the FOMC intended, we again examine the more detailed narrative sources. In these cases, the *Minutes* and *Transcripts* usually provide more explicit information than the *Record of Policy Actions* about the FOMC's intentions. The narrative sources from the subsequent meeting are also often very useful: the *Record of Policy Actions*, *Minutes*, and Bluebooks almost always contain descriptions of what was decided at the previous meeting. We assume that when the FOMC says it made a certain decision at the last meeting, it is not rewriting history.

In the vast majority of cases, either the different sources provide a clear picture of what monetary policy makers intended, or they leave room for only very minor disagreement. In a few cases, however, there is more ambiguity. Sometimes, the narrative sources provide evidence about the direction but not the magnitude of the intended move in the funds rate. In these cases, we rely mainly on the quantitative evidence from the expected funds rate series to deduce the magnitude of the intended action.

Another type of ambiguity concerns asymmetry in the FOMC's decisions. Periodically, when the FOMC decides not to change rates immediately, it makes it clear that any future rate changes will most likely be in a particular direction. When such asymmetry is strong and explicit, we feel it is reasonable to say that the intended funds rate has in fact moved. The likely rate change times the probability of a change is surely not zero. As a starting point, we scale strong asymmetry as one-half of the usual rate change in a given era. For example, for the mid-1970's, when quarter-point moves in the intended funds rate were typical, strong asymmetry is recorded as a change of 1/8 of a point in the intended direction. In the early Burns era, when larger movements were common, strong

of entries for which the expected rate is missing, and for much of the period a range is given rather than a single number. Also, before 1987 the expected series is dated by week rather than by the actual day of the change.

asymmetry may get a value of 1/4 point or more. We then adjust this preliminary estimate of the expected change in the intended funds rate due to asymmetry using the narrative accounts of the meeting. For example, in some cases the narrative accounts make it clear that the asymmetry was being included in the *Record of Policy Actions* mainly for signaling purposes and was unlikely to be acted on. In other cases, the narrative accounts include fairly clear discussions of the magnitude or likelihood of a move.

A final case where the evidence is less than fully clear involves the beginning of the period of nonborrowed reserve targeting under Federal Reserve Chairman Paul Volcker. The FOMC was sufficiently focused on nonborrowed reserve targeting that for many meetings the *Record of Policy Actions* provides only a vague description of the likely implications of the FOMC's decisions for the funds rate. Furthermore, the Federal Reserve's series on the expected funds rate is so volatile from week to week that it is difficult to discern the FOMC's intentions from this source. Finally, neither the *Minutes* nor the *Transcripts* are currently available for late 1979 and 1980. Because of this ambiguity, in our empirical work we check that our results are robust to omitting the early Volcker period.

A meeting-by-meeting description of our application of these general procedures for deducing Federal Reserve intentions is given in an unpublished Appendix available on the AER Web site (http://www.aeaweb.org/aer/contents/). Table A1 at the end of the paper shows the resulting series on the FOMC's intended funds rate before the forecast and the change in the intended rate associated with each FOMC meeting in our sample.

B. *Controlling for the Federal Reserve's Forecasts*

Motivation.—The second step in the derivation of our measure of monetary policy shocks is to remove from the intended series policy actions taken in response to information the Federal Reserve has about future developments. To do this, we need a measure of the Federal Reserve's information. In this regard, it is important to realize that it is only accurate information that matters. If the Federal Reserve bases its actions on inaccurate forecasts, policy will not be preemptively countercyclical except by chance.

The Federal Reserve's internal forecasts provide an excellent proxy for the reliable information about future economic developments that the Federal Reserve possesses and uses. First, the forecasts contain useful information. The Federal Reserve devotes a vast amount of resources to the forecasts, and as a result produces high-quality forecasts. In a previous study, we found that someone having access to a number of well-known private forecasts and the Greenbook forecasts should put substantial weight on the Greenbook forecast and roughly zero weight on the private forecasts in predicting future inflation and real GDP growth (Romer and Romer, 2000). That the Federal Reserve possesses a useful forecast means that successful anticipatory movements are a possibility, and so controlling for them could be important.

The high quality of the Greenbook forecasts makes it likely that they contain most of the useful information about future economic developments known by FOMC members. The forecasts are typically issued just six days before the FOMC meeting, so it is unlikely that much valuable information becomes available between the forecast and the meeting. Indeed, it is the few exceptions that prove this rule: there are a handful of times when the forecast was reissued precisely because important new information became available. We always use the latest forecast to ensure that we control for as much of the Federal Reserve's information as possible.

The records of the discussions at FOMC meetings make it clear that the Greenbook forecasts play a central role in policy deliberations. Many times, especially early in our sample, the staff forecasts are accepted without discussion. There are also many times when members quibble with the forecasts, but those quibbles are symmetric. That is, minor disagreements are expressed, but they are not at all systematic. Much less frequently, the members of the FOMC express disagreement with the staff forecast in one particular direction. However, except in rare instances, these differences are small.

This impression that the Greenbook forecasts are a good summary of the FOMC's information can be tested to some degree after 1979. In its semiannual "Monetary Policy Report to Congress," the Federal Reserve summarizes the forecasts of the individual FOMC members. We compare the midpoints of the reported central tendencies of the members' forecasts of real GDP growth, inflation, and the unemployment rate with the staff forecasts.[5] For the 35 meetings for which we have data, the average absolute difference between the midpoint of the members' forecasts and the staff forecast is 0.28 percentage points for real GDP growth, 0.25 percentage points for inflation, and 0.17 percentage points for the unemployment rate. It certainly does not appear that FOMC members have significant additional information.

The centrality of the Greenbook forecasts in policy discussions, combined with the relative accuracy of the forecasts, suggests that they do contain the vast majority of the useful information about future economic developments upon which the Federal Reserve bases its policy decisions. For this reason, controlling for the Greenbook forecasts should yield a series on Federal Reserve intentions that is largely free of anticipatory movements.

Specification.—To control for the Greenbook forecasts, we estimate the usual relationship between the Federal Reserve's intentions for the funds rate and the forecasts.[6] The Greenbooks contain forecasts for a wide variety of variables. The particular forecasts that we use are those for the growth rate of real GNP/GDP and the GNP/GDP deflator, and for the unemployment rate. These are three key macroeconomic indicators that the FOMC is likely to consider in setting policy.

Both the intended funds rate series that we derive and the forecast data correspond to FOMC meetings. Therefore, at this stage in the analysis, we use FOMC meetings as our unit of observation. In the early part of our sample, the FOMC met at least once a month and sometimes twice. Since 1979, the FOMC has typically met eight times a year. The Greenbook forecasts begin in late 1965, but the forecast horizon was very short (typically just one quarter ahead) until 1969. In addition, the forecasts are only released with a substantial lag. As a result, our analysis is restricted to the period 1969–1996.

The specific equation we estimate is:

$$(1) \qquad \Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \widetilde{\Delta y}_{mi} + \sum_{i=-1}^{2} \lambda_i (\widetilde{\Delta y}_{mi} - \widetilde{\Delta y}_{m-1,i}) + \sum_{i=-1}^{2} \varphi_i \tilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\tilde{\pi}_{mi} - \tilde{\pi}_{m-1,i}) + \rho \tilde{u}_{m0} + \varepsilon_m .$$

Δff_m is the change in the intended funds rate around FOMC meeting m. ffb_m is the level of the intended funds rate before any changes associated with meeting m. It is included to capture any tendency toward mean reversion in FOMC behavior. $\tilde{\pi}$, $\widetilde{\Delta y}$, and $\tilde{u}$ refer to the forecasts of inflation, real output growth, and the unemployment rate. Both the forecasts for the contemporaneous meeting and the change in the forecast since the previous meeting are included because it is plausible that both the levels and the changes in the forecasts are important determinants of Federal Reserve behavior. The i subscripts refer to the horizon of the forecast: -1 is the previous quarter; 0 is the current quarter; and 1 and 2 are one and two quarters ahead, respectively.[7] The forecast for the

[5] When available, we take the information about members' forecasts, along with the comparable staff forecast, from the staff's "chart show" given at the FOMC meetings at which the "Monetary Policy Report to Congress" is discussed (typically the February and July meetings). The chart shows are available on the Board of Governors Web site (http://www.federalreserve.gov). The information is available starting with the meeting for July 1979. We use the forecast of real GDP growth and inflation for the fourth quarter of the previous year to the fourth quarter of the current year, and the unemployment forecast for the fourth quarter of the current year (except for the small number of meetings where only forecasts for annual averages are reported).

[6] The Greenbook forecasts are contained in the document *Current Economic and Financial Conditions*, and are available from the Board of Governors upon request.

[7] The horizons are relative to the date of the forecast corresponding to meeting m. That is, if the meeting is in

previous quarter is often actual data rather than a forecast. We include it because lagged conditions could obviously play a substantial role in FOMC decisions. Using lagged data from the Greenbook is desirable because it reflects what the FOMC believed recent history was *at the time of the meeting*, rather than what our current revised estimates suggest was the case.

We only include forecasts up to two quarters ahead for two reasons. The more prosaic one is that the Greenbooks for the late 1960's and early 1970's rarely forecasted more than two quarters out. As a result, we lose many observations if we try to incorporate longer-term forecasts. The more fundamental reason has to do with policy assumptions. All forecasters, including the Federal Reserve staff, must incorporate assumptions about future policy into their forecasts. The Greenbook forecast is almost always predicated on the assumption of no change in monetary policy in the very short run, where the very short run means at least until the FOMC meeting after the one for which the forecast is being made. This characteristic, along with the usual assumption of some lag in the effects of monetary policy, makes it unlikely that forecasts zero, one, and two quarters ahead are contaminated by assumptions or inside information about the course of monetary policy. As a result, these near-term forecasts provide information about what the Federal Reserve expected to happen to the economy in the absence of changes in monetary policy. At the same time, both output growth and inflation are serially correlated enough that forecasts one and two quarters ahead provide a good indication of the likely forecasted path of the economy over longer horizons.

Because the Okun's Law relationship between output growth and unemployment is so strong, we do not include all horizons of the forecasts of both variables. We focus primarily on forecasts of output growth because it has greater prominence in the Greenbooks, suggesting a more central role in FOMC decision-making. We do, however, include the contemporaneous unemployment forecast so that we control for the current level of the economy as well as forecasted changes.

It is important to note that the goal of this regression is not to estimate the Federal Reserve's reaction function as well as possible. What we are trying to do is to purge the intended funds rate series of movements taken in response to useful information about future economic developments. Once we have accomplished this, it is desirable to leave in as much of the remaining variation as possible. It is this variation that will allow us to identify the effect of monetary shocks on output and inflation. For this reason, in our baseline regression we do not do some of the obvious procedures, such as splitting the sample, that one would do if the goal was to match Federal Reserve behavior as closely as possible. Changes in the tastes or operating procedures of the Federal Reserve are arguably a key source of changes in the intended funds rate that are not correlated with information about future economic conditions, and so should not be removed from the shock series.

Results.—The results of estimating equation (1) are reported in Table 1. The coefficient estimates show that the FOMC tends to behave countercyclically. The sum of the coefficients on the real growth forecasts is 0.04 with a t-statistic of 2.5, and the sum of the coefficients on the changes in the real growth forecasts since the previous meeting is 0.24 ($t = 4.0$). An increase from one meeting to the next in forecasted real growth at all horizons of one percentage point leads to a rise in the intended funds rate of 29 basis points. Although all the estimated coefficients on the growth variables are positive, the strongest estimated effect is for the change in the forecast of real growth for the current quarter. The estimated coefficient on $\widetilde{\Delta y}_{m0} - \widetilde{\Delta y}_{m-1,0}$ is 0.15 ($t = 5.1$). The significant negative coefficient on the forecast of the unemployment rate for the current quarter also confirms the countercyclical tendency in FOMC behavior.

The regression suggests that the Federal Reserve also resists forecasted inflation. The sum of the coefficients on the inflation forecasts is

early July 1980 and the forecast is in late June 1980, the contemporaneous forecast is for the second quarter of 1980. In computing the forecast innovations, the forecast horizons for meetings m and $m - 1$ are adjusted so that the forecasts refer to the same quarter.

TABLE 1—DETERMINANTS OF THE CHANGE IN THE INTENDED FEDERAL FUNDS RATE

	Coefficient	Standard error
Constant	0.171	0.141
Initial level of intended funds rate	−0.021	0.012
Forecasted output growth, Quarters ahead:		
−1	0.007	0.010
0	0.003	0.019
1	0.010	0.032
2	0.022	0.032
Change in forecasted output growth since previous meeting, Quarters ahead:		
−1	0.050	0.030
0	0.152	0.030
1	0.021	0.046
2	0.021	0.051
Forecasted inflation, Quarters ahead:		
−1	0.021	0.024
0	−0.044	0.029
1	0.010	0.044
2	0.052	0.047
Change in forecasted inflation since previous meeting, Quarters ahead:		
−1	0.057	0.045
0	0.003	0.048
1	0.031	0.074
2	−0.062	0.081
Forecasted unemployment rate (current quarter)	−0.048	0.021

Notes: $R^2 = 0.28$; D.W. = 1.84; s.e.e. = 0.39; N = 263. The sample is FOMC meetings over the period 1969:3–1996:12.

0.04 ($t = 2.3$). The sum of the coefficients on the changes in the inflation forecasts is 0.03, but is estimated quite imprecisely ($t = 0.3$). Thus, an increase from one meeting to the next in forecasted inflation at all horizons of one percentage point is associated with a rise in the intended funds rate of seven basis points. All but two of the coefficients on the inflation variables are positive. The largest are for the level of forecasted inflation two quarters ahead and the change in forecasted inflation for the previous quarter.

The magnitudes of these estimated responses are small, particularly for inflation. But we are considering the change in the intended funds rate only over the brief interval from the forecast to the associated FOMC meeting. Therefore, our results merely show that the Federal Reserve's initial responses to output and inflation are modest. Furthermore, the estimated coefficient on the initial level of the intended funds rate is close to zero (−0.021, with a t-statistic of 1.8). Thus, to a first approximation it is the change in the intended rate that depends on economic conditions, as in the rule considered by Andrew Levin et al. (1999). Our estimates therefore imply that in response to, for example, an increase in the level of inflation, the FOMC would not just raise the funds rate immediately, but would continue to increase it at subsequent meetings. In addition, our results do not address the question of how the FOMC behaves between meetings. For both these reasons, our estimates are not informative about how the Federal Reserve adjusts the level of the funds rate to output and inflation over longer horizons.

The R^2 of the regression is 0.28. This suggests that a substantial fraction of Federal Reserve actions over the last three decades have been taken in response to their forecasts of future growth and inflation. Thus, it is certainly possible that not controlling for these responsive actions could bias estimates of the effects of policy. At the same time, that the R^2 is quite far below one indicates that many Federal Reserve actions were taken for reasons unrelated to anticipations of output growth and inflation.

C. *New Measure of Monetary Shocks*

We construct our new measure of monetary shocks by taking the residuals of equation (1). The resulting series shows changes in the intended federal funds rate around FOMC meetings not made in response to forecasts of inflation and real growth.

Because the data used in equation (1) correspond to FOMC meetings, the residuals also correspond to FOMC meetings. Before the shocks series can be used in further analysis, it must be converted to a monthly series. To do this, we assign each shock to the month in which the corresponding FOMC meeting occurred. If there are two meetings in a month, we sum the shocks. If there are no meetings in a

TABLE 2—NEW MEASURE OF MONETARY POLICY SHOCKS
(Percentage points)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1969	0.0	0.0	−0.245	0.405	0.204	−0.020	0.181	0.309	0.029	0.088	−0.005	0.065
1970	−0.160	−0.360	−0.140	−0.145	0.300	−0.180	−0.243	−0.483	−0.272	−0.009	−0.346	−0.229
1971	−0.682	−0.025	−0.065	0.461	0.003	0.343	−0.117	0.0	0.0	−0.322	−0.342	−0.920
1972	−0.234	−0.086	0.252	−0.104	−0.115	−0.050	0.0	0.0	0.0	0.0	0.036	−0.027
1973	0.279	0.225	0.064	−0.063	0.317	0.409	0.115	0.318	−0.571	−0.848	−0.095	−0.165
1974	−0.206	0.201	0.733	0.387	0.392	0.280	−0.091	−0.022	−0.430	−0.284	0.336	−0.229
1975	−0.354	0.243	−0.499	−0.637	0.136	0.170	0.070	−0.136	−0.114	−0.200	−0.281	0.280
1976	−0.091	−0.469	−0.239	0.139	−0.298	−0.038	−0.139	−0.044	0.019	−0.041	0.030	−0.131
1977	−0.097	−0.085	−0.228	−0.049	−0.051	−0.146	−0.240	0.030	0.073	−0.026	−0.048	−0.122
1978	−0.205	0.106	0.042	−0.069	−0.216	0.243	−0.142	−0.064	−0.156	0.133	0.168	−0.042
1979	0.0	−0.152	0.133	−0.064	0.105	0.0	0.761	0.322	−0.224	0.0	0.045	0.0
1980	−0.011	0.197	1.422	−3.221	−0.764	0.0	0.403	−0.198	0.771	1.218	1.871	−0.634
1981	0.0	−0.783	0.307	0.0	1.515	0.0	−0.611	−0.041	0.0	−0.574	−0.356	0.100
1982	0.0	1.021	−0.435	0.0	−0.056	0.0	−0.196	−0.211	0.0	−0.242	0.125	0.651
1983	0.0	0.185	0.145	0.0	−0.019	0.0	−0.008	−0.234	0.0	0.282	−0.172	0.217
1984	0.257	0.0	−0.101	0.0	0.173	0.0	0.327	−0.061	0.0	0.035	−0.546	−0.144
1985	0.0	−0.158	0.201	0.0	−0.104	0.0	0.060	0.186	0.0	0.104	0.021	−0.069
1986	0.0	−0.110	0.0	0.207	0.076	0.0	−0.168	−0.234	0.001	0.0	0.021	−0.082
1987	0.0	0.176	0.191	0.0	0.238	0.0	−0.041	−0.021	−0.147	0.0	−0.085	−0.180
1988	0.0	−0.224	0.018	0.0	0.188	0.308	0.0	−0.182	−0.067	0.0	−0.009	0.446
1989	0.0	0.297	0.061	0.0	0.153	0.0	0.075	−0.139	0.0	−0.087	0.108	−0.067
1990	0.0	0.313	−0.094	0.0	0.044	0.0	−0.066	0.150	0.0	−0.119	−0.018	−0.159
1991	0.0	−0.251	0.227	0.0	0.262	0.0	−0.077	0.140	0.0	−0.035	−0.121	0.113
1992	0.0	−0.004	−0.126	0.0	0.148	0.0	−0.088	−0.003	0.0	−0.175	−0.029	−0.237
1993	0.0	0.094	−0.063	0.0	0.335	0.0	0.009	0.044	0.159	0.0	−0.087	−0.163
1994	0.0	0.224	0.313	0.0	0.287	0.0	0.070	0.417	0.041	0.0	0.549	−0.248
1995	0.0	0.501	0.241	0.0	0.209	0.0	−0.006	−0.091	0.025	0.0	0.052	−0.171
1996	0.073	0.0	0.056	0.0	−0.027	0.0	−0.040	−0.065	−0.042	0.0	0.048	−0.029

month, we record the shock as zero for that month.[8] Table 2 reports our monthly shock series. The top panel of Figure 1 presents a graph of the series, where the monthly values have been summed into quarterly observations to improve readability.

Sources of the Shocks in the New Series.— Estimates of monetary policy "shocks" derived from a regression procedure do not reflect simple random departures by the Federal Reserve from its normal behavior.[9] Rather, they reflect all influences on policy not captured by whatever specification is being used. In our case, because we control for the Federal Reserve's forecasts of the paths of output and inflation, most of those residual influences are appropriate for estimating the impact of monetary policy on the economy.

One important source of our estimated shocks is the evolution of the Federal Reserve's operating procedures. In several parts of our sample, the Federal Reserve placed considerable emphasis on some quantity measure in implementing policy. Concern about the quantity measure often caused the Federal Reserve to set interest rates differently than it otherwise would have given its expectations concerning output and inflation. This is almost surely an important source of the volatility of our shock series in the period of nonborrowed reserve targeting in 1979–1982 and, to a lesser extent, in the period of partial money targeting in the early 1970's.

[8] Recording these observations as zeroes is appropriate. Our shock series shows changes in Federal Reserve intentions for the federal funds rate decided at FOMC meetings that are not systematic responses to forecasts. If there is no meeting, there is no change in Federal Reserve intentions around an FOMC meeting that is not a response to forecasts. There is, therefore, a shock of zero by our measure, not a missing observation.

[9] This point is made persuasively by Rudebusch (2002).

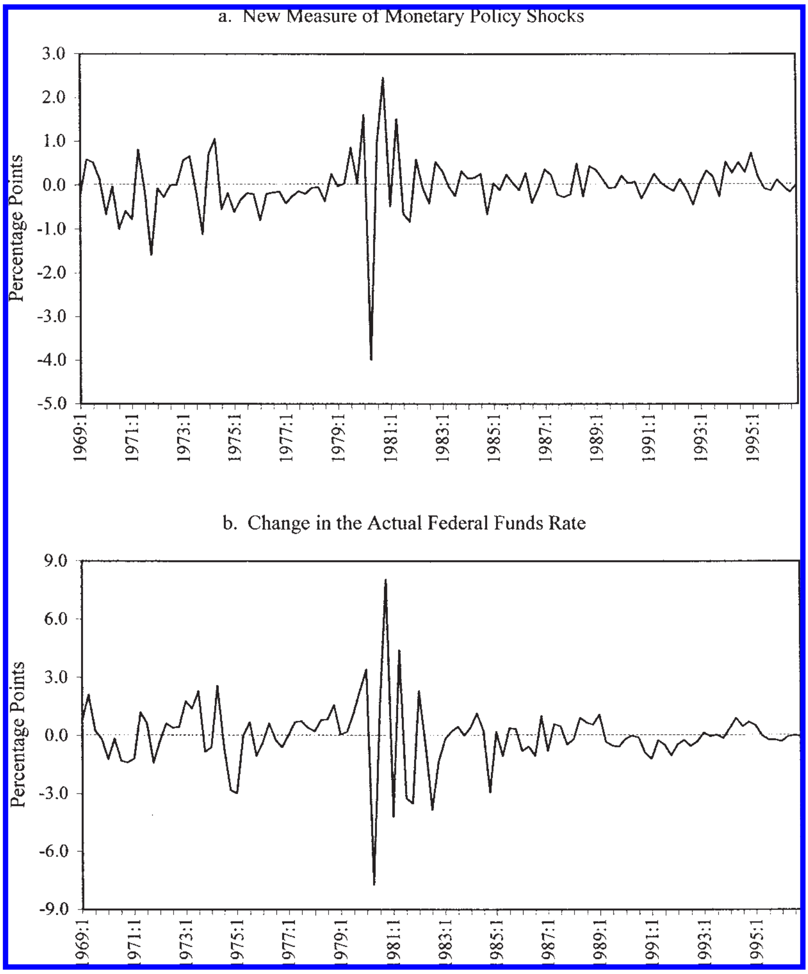

FIGURE 1. MEASURES OF MONETARY POLICY

Policy makers' beliefs about the workings of the economy are another source of shocks. For example, in the early 1970's the prevailing framework at the Federal Reserve held that inflation was extremely unresponsive to economic slack (Romer and Romer, 2002). One would expect this belief to lead the Federal Reserve to set lower interest rates than it otherwise would have. And indeed, our shock series is generally negative in 1971 and 1972.

A third source of shocks are the Federal Reserve's tastes and goals. A Federal Reserve that has a particular distaste for inflation, for example, is likely to set higher interest rates than it typically would. Our series shows obvious upward spikes in 1969, 1973–1974, and 1979–1982. These are three periods that we identified in previous work as times when the Federal Reserve decided that the current level of inflation was too high and that it was willing to endure output losses to reduce it (Romer and Romer, 1989).[10]

[10] These policy shifts involved more than mere changes in tastes, and to a large extent reflected changes in the Federal Reserve's understanding of the economy. Thus there is not a sharp distinction between shocks coming from the Federal Reserve's beliefs and ones stemming from its tastes.

A fourth source is politics. For example, it has been argued that Arthur Burns pursued unusually expansionary policy at the beginning of the Carter administration because he believed it would increase his chances of being nominated for another term (William Grieder, 1987). This may be a reason for the string of negative values of our shock series in 1977.

A fifth source of our estimated shocks is the pursuit of other objectives. For example, at times the Federal Reserve has been concerned about the exchange rate above and beyond any implications exchange rate movements might have for future inflation and output growth. This appears to have been the case in late 1984 and early 1985, when the FOMC repeatedly cited the strength of the dollar as one reason for easing policy (see, for example, Board of Governors, *Annual Report*, 1984, pp. 139–40, and 1985, pp. 87–8). Our shock series shows substantial negative values during this period.

Finally, our estimated shocks also stem from factors reasonably thought of as leading to random variation in policy. Though such factors are, almost by definition, difficult to pinpoint, they include such elements as the personalities, moods, and idiosyncratic views about the state of the economy that the participants bring to the meeting, the persuasiveness of their rhetoric, and so on.

There is one potential source of our estimated shocks that it is not appropriate to use to estimate the effects of monetary policy on output and inflation. To the extent that policy makers employ useful information about the paths of output and inflation beyond what is in the Greenbooks, some of what we classify as shocks will be responses to information about future movements in output and inflation. That is, our series could still include anticipatory actions, and so could lead to biased estimates of the effects of monetary policy. However, because we remove the component of monetary policy actions that represent responses to the Greenbook forecasts, our estimates are very likely to be an improvement over previous estimates. More fundamentally, it is likely that any residual bias is small. Our shock series contains a large amount of variation that is appropriate for identifying the effects of monetary policy. And as discussed above, there is no evidence that monetary policy makers use a substantial amount of additional information in setting policy.

It is also important to point out that our approach excludes some types of policy moves that could be used to estimate the effects of monetary policy. One is moves made in response to incorrect information. For example, policy makers must base their decisions in part on preliminary data, which often contain significant errors. Policy moves resulting from such errors are not responses to correct information about current and prospective economic developments, and so are appropriate for estimating the effects of policy. But because we remove policy makers' normal responses to their beliefs about economic conditions in constructing our measure, we do not include such moves. A second type of potentially useful policy move that we exclude is intermeeting moves not made in response to information about the paths of output and inflation: because we do not have a record of the information that intermeeting moves are based on, we exclude all such moves. As long as what remains in our shock series is not correlated with other factors affecting the path of the economy, however, the exclusion of potentially useful moves will not bias our estimates, but merely make them less precise.

Robustness of the New Series.—The new series is derived by regressing the intended funds rate on the Federal Reserve's internal forecasts and taking the residuals. There are obviously many possible ways of specifying the key regression. One permutation that we consider is to include a quadratic trend in the regression to take into account possible long-run changes in inflation and the level of the intended funds rate. Another is to include the lagged, contemporaneous, and one- and two-quarter-ahead forecasts and forecast innovations for the change in the index of industrial production. Including industrial production could be useful because it is a cyclically sensitive series and one that the Federal Reserve is likely to forecast particularly well (since it constructs the index). A third permutation adds the full complement of unemployment forecasts to the basic specification. Finally, a fourth permutation estimates the regression separately for the pre- and post-1983 periods; this allows us to assess the importance to our results of the changes in Federal Reserve behavior starting in the Volcker era.

The various permutations have some effect on the individual coefficient estimates. However, the sums of the coefficients on the different forecasts and forecast innovations are qualitatively very similar. More importantly, the shock series derived as the residuals of the alternative regressions are all extremely similar to the basic series. The correlation between the permutations and the basic series is over 0.97 in each case. Given that the series being compared do not have a noticeable trend, this degree of correlation is indicative of genuinely similar movements. Thus, our new shock series is robust to a wide array of sensible variations in the specification of the underlying regression.

That splitting the sample has little impact on the estimated reaction function, and therefore on the shock series derived as the residuals, parallels the findings in Athanasios Orphanides (2003). Orphanides finds that the Federal Reserve's behavior is remarkably stable over time when one uses the views of potential output prevailing at the time in measuring the deviation of output from trend. In our case, it is possible that the Federal Reserve has responded to its forecasts in much the same way over our entire sample period, but that the forecasts have become more realistic over time. Consistent with this, Romer and Romer (2002) show that the estimates of the natural rate implicit in the Greenbook forecasts were substantially more optimistic in the late 1960's and the early and late 1970's than they have been in the Volcker and Greenspan eras. It is important to note, however, that if the early forecasts contain some incorrect information, this should only lead us to misclassify some policy moves as responses to information rather than as policy shocks. It should not lead us to classify something as a shock that is not, and therefore should not lead to biased estimates of the effects of policy when our new measure is used.

Broader Measures of Policy.—The main motive for developing the new measure of monetary policy shocks is that broader measures of policy may include endogenous movements and policy changes the FOMC makes in response to information it has about future economic developments. To see if correcting for these potential problems genuinely matters, in the analysis that follows we compare the results using our new series with those using broader measures of policy. Because the new measure is based on interest rates, it is desirable to compare it with other interest rate measures. The key broader measure that we consider is the change in the actual federal funds rate.[11] This is clearly the most commonly used indicator of monetary policy (see, for example, Bernanke and Alan S. Blinder, 1992; Sims, 1992; Christiano et al., 1996).

The change in the actual funds rate is given in the lower panel of Figure 1.[12] As one would expect given the derivation of our new series, the broad movements in the new series and the change in the funds rate are usually similar. The early Volcker era, for example, is a period of extreme volatility in both series. Likewise, 1969 and 1973–1974 are periods of contraction in both series, while 1971 and 1975 are periods of expansion in both series. The contemporaneous correlation between our new measure of monetary shocks and the change in the actual funds rate over the entire sample period is 0.43.

However, the behavior of the two series is sometimes quite different. For example, our shock series shows a string of negative values in the early Carter era (1977 and 1978), while the change in the actual funds rate shows a string of positive values. This difference shows the importance of controlling for the forecasts: while the Federal Reserve was raising interest rates in this period, it was raising the funds rate by less than it normally would have given its forecasts of rapid growth and high inflation. Therefore, what shows up as a contraction in the actual funds rate is a period of substantial expansion in our new series. Controlling for forecasts also explains why some contractions are larger outliers in our new series than in the actual funds rate. For example, the new series shows two quarters of relatively extreme tightening in

[11] The federal funds rate data are from the Board of Governors Web site. We use the change in the monthly average of the funds rate to minimize the effects of extreme day-to-day variation.

[12] Again, to improve readability we present the quarterly sums of the monthly changes. Note that the scale is different in the two panels of Figure 1. The new monetary shocks series shows smaller movements than the actual funds rate.

early 1974, while the actual funds rate falls slightly in the first quarter of 1974 and rises moderately in the second. The movements in the actual funds rate in both quarters were unusual given the fact that the Federal Reserve was forecasting severe economic decline, and so show up as relatively extreme contractions in the new measure.

As the derivation of the new measure makes clear, our series differs from the change in the actual funds rate in two ways: we consider only intended movements in the funds rate around FOMC meetings, and we exclude movements that are the FOMC's normal response to anticipated economic developments. We will therefore also consider two intermediate broader series in our comparisons. The first is the change in the intended funds rate around FOMC meetings. This shows the effects of focusing on intended movements without controlling for information about prospective economic developments, and so addresses endogeneity but not anticipatory policy actions. Thus, this comparison will show the bias that might result from using a series on the change in the funds rate target in empirical analysis.

The second intermediate series is the residuals from a regression of the change in the actual funds rate on the Greenbook forecasts [that is, the residuals from equation (1) with the change in the funds rate as the dependent variable].[13] As described above, because many of the movements in the funds rate occur between meetings, the Greenbook forecasts are a highly imperfect control for the information underlying the overall change in the funds rate from one meeting to the next. Nevertheless, this series shows the effects of controlling for some of the information the Federal Reserve possesses about prospective developments, and thus partially removes anticipatory movements. Because it does not restrict attention to intended movements, the series does not address short-run endogeneity. The results based on this series will show the effects of simply including the Greenbook forecasts as control variables in empirical studies of the effects of monetary policy.

II. Implications of the New Measure

The next step in our analysis is to use the new measure of monetary policy shocks to estimate the effects of policy. We first examine the impact of policy on output and on prices in simple, single-equation regressions. We then examine the impact of policy in a single-equation framework with an explicit control for supply shocks, and in a vector autoregression framework.

A. *Output*

Methodology.—We want to determine how output behaves in the wake of monetary shocks. The obvious way to do this is simply to regress output growth on a constant, its own lagged values, and lagged values of the new policy measure. The lagged values of the shock series are included to capture the direct impact of shocks on output growth, and the lagged values of output growth are included to control for the normal dynamics of output.

A natural variation on our approach is to control for other variables that may affect output. Since we control for the Federal Reserve's information about future output growth in constructing the measure of policy changes, there is no reason to expect the measure to be correlated with other variables that influence output. Our basic specification therefore does not include any controls. We show below that controlling for a measure of supply shocks has little impact on the results. Similarly, an obvious alternative to our one-equation approach is to run a vector autoregression with output growth and the policy measure (and perhaps other variables). We show below that using our new policy measure in a VAR yields results similar to those in our basic specification.

Because our measure of monetary policy is

[13] This regression requires the change in the funds rate using meetings rather than months as the unit of observation. Conceptually what one wants is the change in the funds rate from just before the forecast for one FOMC meeting to just before the forecast for the next meeting. To minimize the effects of day-to-day fluctuations in the funds rate, and because the forecasts are typically issued on Wednesdays, we use the average for the week ending on the Wednesday of the week that includes the date of the forecast. The weekly averages are from the Board of Governors Web site. We then estimate equation (1) using this series in place of the change in the intended funds rate around the meeting (and using the average funds rate for the week of the forecast in place of the intended rate before the forecast). We then take the residuals and convert them to a monthly series in the same way we do for our shock series.

monthly, we use industrial production as our output series.[14] To avoid the complications introduced by the government's seasonal adjustment algorithm, we use data that have not been seasonally adjusted and include monthly dummies in the regression.[15] In our baseline regression, we include 24 lags of output growth and 36 lags of the monetary policy measure. We make the conventional assumption that monetary policy does not affect output within the month; thus we do not include the contemporaneous value of the shock series.[16]

Our baseline regression is therefore:

$$(2)\quad \Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{t-j} + e_t,$$

where y is the log of industrial production, S is our new measure of monetary policy shocks, and the D_k's are monthly dummies. Our sample period is 1970:1–1996:12, with the values of S_t before 1969:3 set to zero. The end date is the last month for which our policy measure is available. The start date is chosen so that a reasonable number of lagged values of the policy measure are available at the beginning of the sample.

We summarize the results by examining the response of the level of log output to a one-time realization of our monetary policy variable (S) of one percentage point. The estimated response of log output after one month is just c_1, the coefficient on the first lag of S; the estimated response of log output after two months is $c_1 + (c_2 + b_1 c_1)$; and so on. As can be seen in Table 2, the realization we consider is a substantial shock, roughly the size of that in March 1974. However, it is only about one-third the size of the largest shock in our sample.

Results.—The estimates of equation (2) are given in Table 3. The coefficients on the first two lags of our shock variable are positive, and the first is significantly larger than zero. The coefficients then turn sharply negative: all but two of the estimated coefficients on lags 3 through 27 are negative, although most of them are not individually significant. Starting with lag 28, the coefficients are all positive, though again few are significant.

Figure 2 shows the implied response of log output to a realization of the policy measure of one percentage point, together with one-standard-error bands.[17] The estimated cumulative impact is slightly positive for the first four months, and then declines roughly linearly through month 22. The estimated effect is essentially flat at −4.3 percent in months 22 through 27. This means that a one-percentage-point rise in the Federal Reserve's intentions for the funds rate, not taken in response to information about future economic developments, reduces industrial production by over 4 percent. The impact then weakens gradually, reaching −1.7 percent at month 48. The estimated impact in the middle months is highly significant: the t-statistic for the estimated effect in each of months 17 through 27 exceeds 2.5. The two-standard-error confidence interval for the impact in month 22 is (−7.0%, −1.4%). The effect at longer horizons, on the other hand, is not precisely estimated. The two-standard-error confidence interval in month 48 is

[14] The industrial production data are from the Board of Governors Web site. We use series B50001 in its non-seasonally-adjusted form.

[15] We have also run all of the regressions in the paper using seasonally adjusted data and excluding the monthly dummies. None of the results are sensitive to this change.

[16] The same logic that implies that one does not need to include controls implies that it is not necessary to include the lagged values of output growth. This specification has the added advantage that if monetary policy affects output contemporaneously, the estimated effects of policy on output growth in later months will not be biased. We find that excluding the lags of the dependent variable has little effect on any of our estimates, but that it reduces the standard errors substantially.

[17] The standard errors are computed by Monte Carlo methods. Specifically, we repeatedly draw coefficients from a multivariate normal distribution with mean and variance-covariance matrix given by the point estimates and variance-covariance matrix of the regression coefficients. For each draw, we compute the implied response of output to a realization of S of one percentage point. The standard error for the response at month h is then the standard deviation across the different draws of the estimated responses at month h. The standard errors used in constructing the figures are based on 500 draws.

TABLE 3—THE IMPACT OF MONETARY POLICY SHOCKS ON INDUSTRIAL PRODUCTION

Monetary policy shock			Change in industrial production		
Lag	Coefficient	Standard error	Lag	Coefficient	Standard error
1	0.0038	0.0018	1	0.063	0.064
2	0.0026	0.0018	2	−0.013	0.063
3	−0.0038	0.0018	3	0.107	0.063
4	−0.0012	0.0018	4	0.048	0.063
5	−0.0039	0.0018	5	0.028	0.063
6	−0.0001	0.0018	6	−0.005	0.063
7	−0.0008	0.0019	7	0.018	0.063
8	−0.0029	0.0019	8	0.008	0.063
9	−0.0021	0.0019	9	0.040	0.062
10	−0.0047	0.0018	10	−0.043	0.061
11	−0.0025	0.0019	11	0.071	0.059
12	−0.0035	0.0019	12	0.287	0.060
13	−0.0021	0.0019	13	0.023	0.061
14	−0.0007	0.0018	14	−0.196	0.060
15	−0.0003	0.0019	15	−0.151	0.061
16	0.0019	0.0018	16	−0.128	0.062
17	−0.0009	0.0018	17	0.078	0.063
18	−0.0024	0.0018	18	0.085	0.063
19	−0.0023	0.0019	19	0.056	0.063
20	−0.0007	0.0019	20	0.081	0.063
21	−0.0011	0.0019	21	−0.060	0.063
22	−0.0032	0.0018	22	−0.017	0.063
23	0.0015	0.0019	23	−0.068	0.063
24	−0.0000	0.0019	24	0.086	0.063
25	−0.0001	0.0019			
26	−0.0000	0.0019			
27	−0.0007	0.0019			
28	0.0038	0.0019			
29	0.0013	0.0019			
30	0.0035	0.0019			
31	0.0018	0.0019			
32	0.0009	0.0018			
33	0.0014	0.0018			
34	0.0047	0.0018			
35	0.0011	0.0018			
36	0.0024	0.0018			

Notes: $R^2 = 0.86$; D.W. = 2.01; s.e.e. = 0.009; N = 324. The sample period is 1970:1–1996:12. Coefficients and standard errors for the constant term and monthly dummies are not reported.

(−6.4%, +3.0%). Thus it encompasses both no effect and the estimated maximum impact.[18]

Since it is not plausible that contractionary policy raises output, the finding of a significant positive coefficient on the first lag of the shock

[18] These results are similar in their essentials to those in our earlier work on the real effects of monetary policy (Romer and Romer, 1989, 1994). In the earlier papers we identified only a very specific type of shock: Federal Reserve decisions to contract aggregate demand in order to reduce inflation from its current level. We found that the maximum impact of such a decision on industrial production was a reduction of 12 percent after 32 months. Like our new measure, this anti-inflation shock variable is designed to isolate changes in monetary policy not taken in response to anticipated developments. It is, however, not calibrated as the new measure is, and does not include expansionary shocks. The obvious reason that the earlier studies found a larger effect is that the average shock is much larger: in the seven episodes we identify, the actual monthly funds rate rose an average of 3.6 percentage points (measured as the difference between the low in the six months before the shock to the high in the six months after the shock). The finding that the lags with which policy affects output are longer for these shocks than for our new measure could stem from the fact that important interest rate movements often occurred after the decisions to follow tighter policy that we identify.

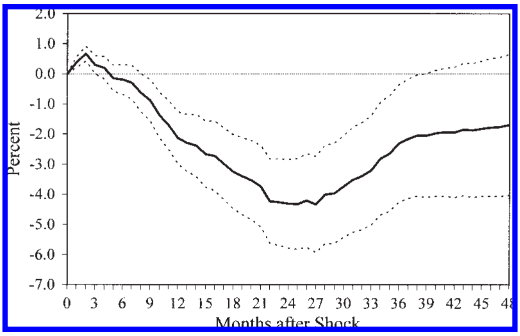

FIGURE 2. THE EFFECT OF MONETARY POLICY ON OUTPUT

variable is troubling. Closer inspection of the data reveals that this result is due to the April 1980 observation. Our shock measure for April 1980 is −3.2 percentage points, and industrial production fell 2.5 percent (seasonally adjusted) from April to May. Setting the April shock to zero lowers the coefficient on the first lag from 0.0038 to 0.0023, and the *t*-statistic from 2.1 to 1.1. Examination of the *Record of Policy Actions* for the April 1980 meeting yields no evidence that the FOMC's decision to ease aggressively was based on information about unfavorable economic prospects beyond the information contained in the Greenbook forecast. Indeed, if anything the members' outlook may have been less pessimistic than the forecast. Thus, there is no reason to think that our shock series is mismeasured. The most likely possibility is therefore that the positive coefficient on the first lag of our shock variable reflects sampling error due to the single extreme observation.

Robustness.—We investigate the robustness of these results along four dimensions. First, because our estimated policy changes are largest and least certain during the early part of the period of nonborrowed reserve targeting under Paul Volcker, we reestimate equation (2) treating the policy measure as missing from October 1979 through May 1981. Omitting these observations weakens the results only slightly. The estimated peak effect is now −3.4 percent rather than −4.3 percent, and the estimated effect after 48 months is +0.2 percent rather than −1.7 percent. The omission of the information from the early Volcker era raises the standard errors of the estimated effects only by about 10 percent.

Second, we examine the effects of including 48 rather than 36 lags of the policy measure. This change has virtually no impact on the point estimates or standard errors through month 36. Thereafter the inclusion of the additional lags increases the extent of mean reversion. With the additional lags, the estimated impact at month 48 is −0.8 percent rather than −1.7 percent.

Third, we investigate the robustness of our findings to alternative specifications of the regression used to derive the shock series. Using any of the alternative shock series described in Section I, subsection C, leads to very similar estimates of the effect of monetary shocks on output. For example, using the residuals from the regression of the intended funds rate on Federal Reserve forecasts estimated separately before and after 1983 leads to an estimated peak effect of monetary policy on output of −3.9 percent.

Fourth, we examine the effects of controlling for a measure of supply shocks. We describe this experiment in Section II, subsection C, below.

Broader Measures of Policy.—It is important to compare the results using our measure with those using broader measures. A finding that the estimated effects of policy on output are similar using both our new measure and broader measures would suggest that the broader measures are not severely contaminated by endogenous and anticipatory movements, and thus would allow researchers to use those measures with more confidence. A finding that the estimated effects are very different, on the other hand, would suggest that using a narrower measure such as ours is important.

To investigate this issue, we reestimate equation (2) using the change in the actual funds rate in place of our shock series. The top panel of Figure 3 displays the estimated response of output to a one-percentage-point rise in the funds rate. The effects of policy using the change in the actual funds rate are both substantially slower and considerably smaller than with our measure. The estimated effect becomes negative beginning in month 6, only a month later than it does with our measure. However, the effect is close to zero through month 10, and is less than a third as large as with our measure through month 17. The effect reaches −2.4

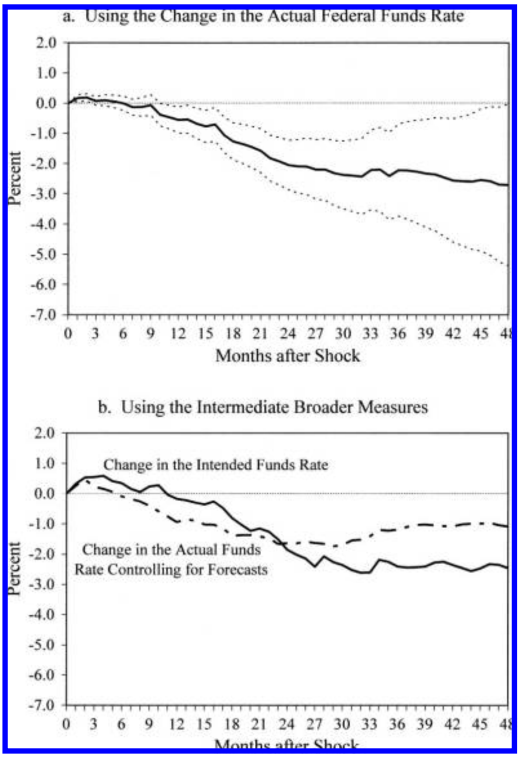

FIGURE 3. THE EFFECT OF BROADER MEASURES OF MONETARY POLICY ON OUTPUT

percent in month 30 and is roughly flat thereafter. With our measure, in contrast, the estimated effect peaks at −4.3 percent in months 22–27. At all horizons, there is considerable overlap between the two-standard-error confidence intervals using the actual funds rate and using our new series. Nonetheless, the contrast between the point estimates using the two measures suggests that endogenous and anticipatory movements in interest rates have a quantitatively important impact on the estimated speed and size of the effect of policy on output.[19]

We also estimate equation (2) using the change in the intended funds rate and the change in the actual funds rate controlling for the forecasts. The results are shown in the bottom panel of Figure 3. The results using both intermediate broader series are similar to those obtained using the change in the actual funds rate. That the results using both intermediate series are quite different from those using the new measure, and similar to those using the actual funds rate, suggests that dealing with both endogeneity and anticipatory movements is important to estimating the effects of policy. Indeed, the fact that neither correction alone has a large impact, while the two together clearly do, suggests that there are important interaction effects between the two corrections.

B. *Prices*

Methodology and Basic Results.—Our new series can also be used to estimate the impact of monetary policy on inflation and the price level. While there are few broad monthly output measures, there are a number of reliable monthly price indexes to choose from. In our baseline regressions we use the PPI for finished goods, which is a standard measure covering a wide range of goods.[20] We discuss the results using other common measures below.

[19] As Figure 1 makes clear, the actual funds rate is substantially more volatile than our new measure. If the two series are highly correlated, this difference in volatility could account for some of the difference in the estimated effects of policy when we consider the same one-percentage-point innovation in each series. To investigate this issue, we first regress the change in the actual funds rate on 24 own lags and the contemporaneous value and 36 lags of our new shock measure, and compute the implied response of the actual funds rate to a one-percentage-point realization of our new measure. We find that the funds rate rises more than one-for-one with our measure for the first few months following a shock, but quickly falls to zero (and then below). We then compute what the coefficients from equation (2) (estimated using the actual funds rate) imply about how industrial production responds to this path of the funds rate. That is, we calculate the response of output, not to a one-percentage-point rise in the funds rate, but to the usual response of the funds rate to a one-percentage-point realization of our new measure. We find that only about half of the gap between the maximum effect estimated using our measure and the maximum effect estimated using the funds rate goes away when we make this change. At shorter horizons, an even smaller portion of the gap is eliminated. Furthermore, because the estimated effects of the actual funds rate on output are close to zero for ten months, changing the path of the funds rate considered has no effect on the speed of the output response. Therefore, our finding that output responds more quickly using our new measure than using the actual funds rate is robust to considering the alternative path for the funds rate.

[20] The PPI data are not seasonally adjusted. They are from the Bureau of Labor Statistics Web site (http://wwwbls.gov), series WPUSOP3000.

Our approach parallels the one we use to examine the impact of policy on output. The one change is that because there appear to be longer lags in the impact of policy on prices, our basic specification includes 48 rather than 36 lags of the policy measure. Thus our baseline regression is

$$(3)\quad \Delta p_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta p_{t-i} + \sum_{j=1}^{48} c_j S_{t-j} + e_t,$$

where p is the log of the PPI for finished goods. The estimates are reported in Table 4.

Figure 4 shows the estimated cumulative impact on the PPI for finished goods of a realization of our policy measure of one percentage point, together with one-standard-error confidence bands. The estimated impact is virtually zero for the first 22 months after the shock. The price level rises for the first eight months, but the maximum impact is just 0.3 percent and is not close to statistically significant. Two years after the contractionary policy shock, prices begin to fall substantially. The estimated impact is −1.9 percent after 30 months and −5.9 percent after 48 months. The effect becomes progressively more statistically significant. The t-statistic reaches 2 (in absolute value) in month 29, 4 in month 37, and 5 in month 43. The two-standard-error confidence interval for the effect after 48 months is (−8.0%, −3.7%).[21]

The finding that inflation slows only after a substantial delay raises the possibility that our policy measure still contains some anticipatory actions, so that the true effect of policy is faster and larger than our estimates imply. However, two considerations suggest that this is unlikely. First, the possibility that the FOMC has important information about inflation beyond what is in its forecasts seems most plausible for very short horizons. If the FOMC were setting policy on the basis of additional information about the very near term, one would expect to see a clear positive estimated impact of policy on inflation at short horizons followed by a negative impact. But instead, we find no clear effect for two years. Second, as described below, when we add commodity prices—which is the series most often thought to provide additional information about future inflation—to the inflation regression, the estimated effects of policy on prices are no faster or stronger than before. Indeed, if anything they are weaker. Thus, the most likely possibility is that there are genuinely long delays in the impact of monetary policy on inflation.

Robustness.—These results do not depend on the large swings in our policy measure in the early Volcker period. Treating the measure as missing from October 1979 through May 1981 has virtually no impact on the point estimates. The standard errors increase by about 20 percent, but the effects remain overwhelmingly significant.

Using the shock series derived from the alternative specifications of the regression of the intended funds rate on Federal Reserve forecasts also has little impact on the results. For example, a one-percentage-point innovation in the shock series derived using separate regressions on Federal Reserve forecasts before and after 1983 has a cumulative impact on the price level of −6.6 percent after 48 months. At the same time, using these alternative shock series typically increases the standard errors, though never by enough to render the estimated impact insignificantly different from zero.

Our results are also robust to the measure of prices. We reestimate equation (3) using both the CPI excluding shelter and the chain-type price index for personal consumption

[21] Our shock series accounts for a moderate amount of the nonseasonal variation in both output growth and inflation. Consider, for example, equations (2) and (3) estimated with seasonally adjusted data and without the seasonal dummies. For the output equation, (2), excluding the shock variables lowers the R^2 of the regression from 0.414 to 0.281. For the price equation, (3), it lowers the R^2 from 0.483 to 0.340. Our shock series reflects only a subset of independent shifts in monetary policy, and obviously much of the month-to-month variation in both output growth and inflation stems from idiosyncratic sources. Thus, the explanatory power of the shock series is substantial.

TABLE 4—THE IMPACT OF MONETARY POLICY SHOCKS ON PRICES

Monetary policy shock			Change in producer prices		
Lag	Coefficient	Standard error	Lag	Coefficient	Standard error
1	0.0006	0.0009	1	0.192	0.065
2	0.0001	0.0009	2	0.002	0.065
3	−0.0005	0.0009	3	−0.038	0.065
4	0.0010	0.0009	4	−0.098	0.065
5	0.0014	0.0009	5	0.009	0.066
6	−0.0006	0.0009	6	0.107	0.065
7	0.0001	0.0009	7	−0.056	0.065
8	0.0005	0.0009	8	0.050	0.065
9	−0.0013	0.0009	9	0.074	0.065
10	0.0009	0.0009	10	−0.049	0.065
11	−0.0016	0.0009	11	0.087	0.065
12	−0.0003	0.0009	12	0.127	0.065
13	0.0001	0.0009	13	−0.071	0.065
14	−0.0002	0.0009	14	−0.020	0.064
15	0.0010	0.0009	15	−0.019	0.064
16	−0.0004	0.0009	16	−0.018	0.063
17	0.0003	0.0009	17	0.056	0.063
18	−0.0012	0.0009	18	0.029	0.063
19	0.0005	0.0009	19	0.009	0.062
20	−0.0020	0.0009	20	0.093	0.063
21	0.0002	0.0009	21	0.004	0.063
22	−0.0001	0.0009	22	−0.004	0.063
23	−0.0013	0.0009	23	−0.057	0.062
24	−0.0019	0.0009	24	0.045	0.061
25	−0.0024	0.0009			
26	−0.0025	0.0010			
27	−0.0017	0.0010			
28	−0.0002	0.0010			
29	−0.0022	0.0010			
30	−0.0033	0.0010			
31	−0.0031	0.0010			
32	−0.0006	0.0010			
33	−0.0013	0.0010			
34	−0.0010	0.0010			
35	−0.0015	0.0010			
36	−0.0033	0.0010			
37	−0.0019	0.0010			
38	−0.0016	0.0010			
39	0.0001	0.0010			
40	−0.0017	0.0010			
41	−0.0007	0.0010			
42	−0.0029	0.0010			
43	−0.0013	0.0010			
44	−0.0003	0.0009			
45	−0.0014	0.0009			
46	0.0001	0.0009			
47	−0.0015	0.0009			
48	−0.0008	0.0009			

Notes: $R^2 = 0.57$; D.W. = 2.00; s.e.e. = 0.005; N = 324. The sample period is 1970:1–1996:12. Coefficients and standard errors for the constant term and monthly dummies are not reported.

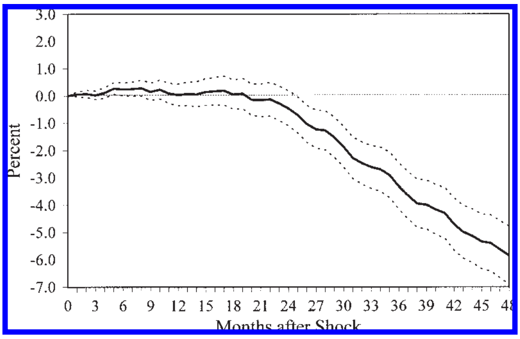

FIGURE 4. THE EFFECT OF MONETARY POLICY ON THE PRICE LEVEL

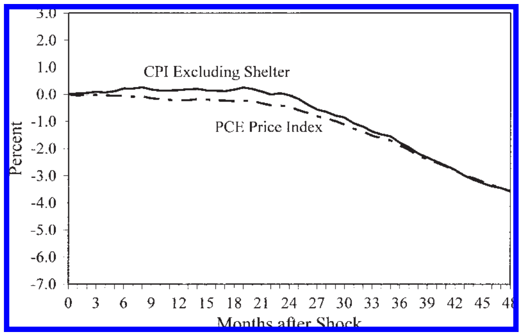

FIGURE 5. THE EFFECT OF MONETARY POLICY USING ALTERNATIVE MEASURES OF THE PRICE LEVEL

expenditures from the National Income and Product Accounts.[22] The estimated responses of these series to a realization of our policy measure of one percentage point are given in Figure 5. Using either alternative, the price effects of a monetary shock remain large and overwhelmingly significant. There are two interesting differences from our baseline results. First, the effects are somewhat smaller: with either alternative, the impact after 48 months is −3.6 percent ($t = 4.3$ for the CPI excluding shelter and 5.0 for the PCE price index), as opposed to −5.9 percent ($t = 5.5$) when the PPI for finished goods is used. Second, when we use the PCE price index (but not the CPI excluding shelter), the estimates suggest that the price level turns lower immediately after a shock. The estimated short-run price effects are quite small, however; for example, the estimated effect after 18 months is −0.3 percent ($t = 0.8$).

Broader Measures of Policy.—We again compare the results using our new policy measure with those obtained using the change in the actual federal funds rate. Since the results are similar for all three price measures, in this and all subsequent analysis we only report the results using the PPI for finished goods. The top panel of Figure 6 shows the estimated cumulated response of the price level to a one-percentage-point rise in the actual funds rate. The estimates imply that the price level rises by about 1 percent over the first two years after a contractionary move and is then essentially constant. Thus, the point estimates are radically different from those using our new measure. Moreover, in contrast to the results for output, for prices the two-standard-error confidence intervals using the actual funds rate and using our new measure are far apart. At 48 months, for example, the confidence interval is (−1.4%, +3.3%) using the actual funds rate and (−8.0%, −3.7%) using the new measure.

This finding that prices typically rise rather than fall after Federal Reserve tightenings when policy is measured using the funds rate is representative of the "price puzzle" found by many previous studies. The fact that there is a strong price puzzle when the actual funds rate is used, but not when our new measure is used, strongly suggests that the funds rate is contaminated by endogenous and anticipatory movements. As a result, it yields inaccurate estimates of the effects of policy, at least in the simple specifications we consider. The next two subsections address the question of whether the funds rate can nevertheless yield accurate estimates in more complicated specifications.[23]

The bottom panel of the figure shows the

[22] The CPI data are from the Bureau of Labor Statistics Web site, series CUUR0000SA0L2. The PCE data are from the Bureau of Economic Analysis Web site (http://www.bea.gov), series P1PCEG B. Because the PCE price index is only available in seasonally adjusted form, in the regression using this series we omit the seasonal dummies.

[23] Because the estimated price effects using the actual funds rate and using our new measure are of opposite signs, considering the alternative path of the funds rate discussed in footnote 19 does not eliminate the fundamental difference between the two sets of estimates.

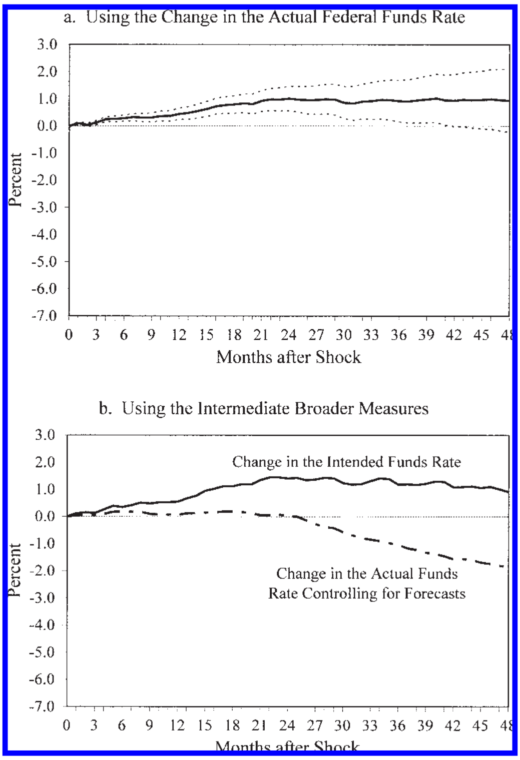

FIGURE 6. THE EFFECT OF BROADER MEASURES OF MONETARY POLICY ON THE PRICE LEVEL

effects of using our two intermediate broader measures: the change in the intended rate around FOMC meetings, and the residuals from a regression of the change in the actual funds rate on the Greenbook forecasts. When we use the change in the intended funds rate around FOMC meetings but do not control for the forecasts, the results are similar to those using the change in the actual funds rate. When we control for the forecasts but do not restrict our attention to intended changes in the funds rate, the results show a very slow and weak effect of policy on prices: the price level does not turn down until 25 months after a shock, and after 48 months it is only 1.9 percent lower ($t = 2.8$). These estimated effects are roughly midway between those using the change in the actual funds rate and those using our shock series.

That the results for both intermediate broader measures are quite different from those using our new measure suggests again that considering only intended interest rate changes and controlling for the Federal Reserve's forecasts are both critical to estimating the effects of policy. At the same time, the fact that using the funds rate controlling for the forecasts moves the results noticeably closer to those using our new measure suggests that, at least for prices, anticipatory movements are the more important source of bias when the actual funds rate is used as the measure of policy.

C. *Supply Shocks*

Motivation.—We have attempted to remove anticipatory movements from our measure of monetary policy shocks by controlling for the Federal Reserve's internal forecasts. However, it is obviously possible that some such movements are still present in our measure. Remaining anticipatory policy moves could be the result of the Federal Reserve having additional information about either supply shocks or demand shocks that is not included in the forecasts.

The literature on the effects of monetary policy has tended to emphasize the consequences of uncaptured responses to supply shocks. If some of the changes that an econometrician interprets as policy shocks are in fact responses to supply shocks that will lower output in the future, this would lead to overestimates of the strength of the negative relationship between contractionary policy shocks and output. Likewise, because a supply shock will raise inflation in the future, uncaptured responses to supply shocks would lead to underestimates of the negative effect of contractionary policy on prices and, in extreme cases, to a finding of a positive correlation between prices and monetary contraction.

This literature has suggested that an index of world commodity prices is a particularly timely indicator of supply shocks. Adding world commodity prices to our regressions therefore provides a test of whether our new measure still includes some policy moves taken in response to supply shocks. If adding this measure of supply shocks makes the estimated impact of policy on output weaker (that is, less negative) and its estimated impact on prices stronger (more negative), this would indicate that our new measure is positively correlated with supply shocks. This would suggest that our

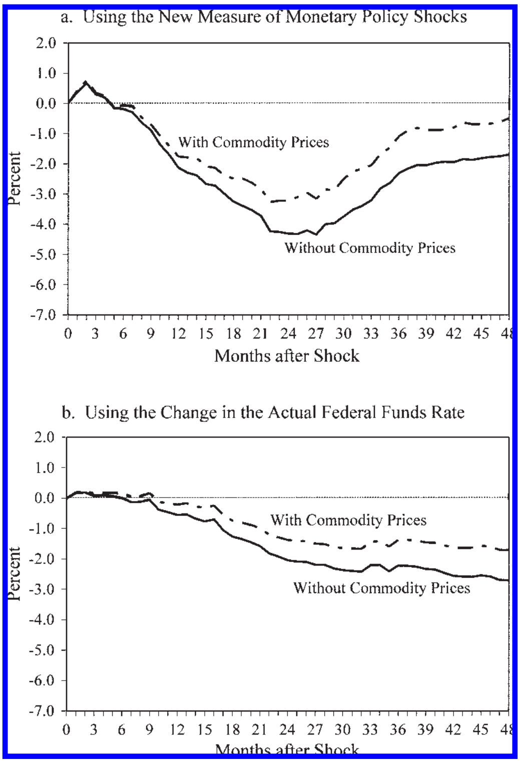

FIGURE 7. THE EFFECT OF MONETARY POLICY ON OUTPUT WITH AND WITHOUT COMMODITY PRICES

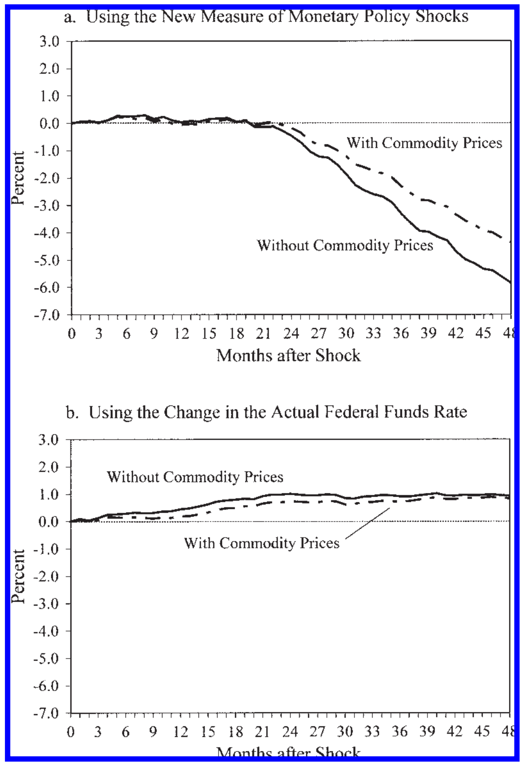

FIGURE 8. THE EFFECT OF MONETARY POLICY ON THE PRICE LEVEL WITH AND WITHOUT COMMODITY PRICES

measure is still somewhat contaminated by anticipatory movements. But if controlling for a broad measure of supply shocks has no important effect on the estimates, this would strongly suggest that our measure largely reflects independent changes in policy.

Including Commodity Prices in Our Basic Specification.—To investigate the effects of controlling for commodity prices, we add the contemporaneous value and 12 lags of the percentage change in world commodity prices to our basic output and price regressions.[24] The results are shown in the top panels of Figures 7 and 8. They give no hint that unmeasured responses to supply shocks are affecting our results. The idea that the Federal Reserve has important additional information about supply shocks is most plausible for short horizons. Yet the estimated short-run effects of policy are virtually unaffected by controlling for commodity prices. For output, there is no discernible change in the impact of policy for the first five months. For prices, this is true for the first 20 months.

Controlling for commodity prices does change the estimated impacts moderately thereafter. For output, the estimated impacts are slightly smaller than before. The estimated cumulative effect is −1.8 percent rather than −2.1 percent after 12 months, and −3.2 percent rather than −4.3 percent after 24. These differences, though small and delayed, are in the direction one would expect if a portion of what we identify as policy shocks are actually responses to supply shocks.

For prices, however, the estimated impact of policy in fact *falls* moderately when we control for commodity prices. It is −0.2 percent rather than −0.5 percent after 24 months, and −4.4

[24] The series that we use is the index of world commodity prices from International Financial Statistics (series CMPRI02).

percent rather than −5.9 percent after 48. This is the opposite of what one would expect if our measure were contaminated by responses to supply shocks. In short, the impact of controlling for commodity prices is small and does not fit the pattern one would expect if our new measure still included important responses to supply shocks.

Including Commodity Prices in the Regression Using a Broader Measure of Policy.—As described above, the previous literature has suggested that an index of commodity prices captures the most important information to which the Federal Reserve responds. It therefore argues that including this measure of supply shocks in regressions estimating the effects of monetary policy using broad policy indicators is enough to deal with the problem of anticipatory movements. And, indeed, previous work has found that including world commodity prices largely eliminates the price puzzle.

But, the fact that the estimates have the anticipated sign does not mean they are free of bias. There are clearly other possible sources of uncaptured anticipatory policy movements. Most obviously, the Federal Reserve surely responds to anticipated inflation caused by demand shocks as well as by supply shocks. In addition, there could be indicators of supply shocks other than commodity prices that the Federal Reserve responds to. As a result, the estimates of the effects of monetary policy derived using broad measures of policy controlling for world commodity prices may still yield inaccurate results.

To address this issue, we add commodity prices to our regressions that use the change in the actual funds rate. As before, we include the contemporaneous value and 12 lags of the change in commodity prices. The results of this exercise are presented in the bottom panels of Figures 7 and 8. The estimates of the impact of monetary policy move in the direction one would expect: both the estimated declines in industrial production and the estimated rises in producer prices in response to contractionary monetary policy become slightly weaker when commodity prices are controlled for. This supports the standard view that changes in the funds rate include a component that represents responses to supply shocks rather than independent changes in policy.

Crucially, however, the estimated effects of policy when commodity prices are included in the regressions continue to be very different when the actual funds rate is used as the measure of policy than when our new measure is used. For output, the estimated impact of policy for the first two years remains about two to three times weaker when the actual funds rate is used than when our measure is used. For prices, for our particular specification and sample, controlling for commodity prices does not even eliminate the price puzzle from the results that use the actual funds rate: the estimated impact of policy on prices remains positive (though it is no longer ever significantly different from zero). With our measure, in contrast, the estimated effects of policy are negative, large, and statistically significant either with or without controlling for commodity prices. We take this as strong evidence that controlling for commodity prices is not enough to solve the difficulties with the funds rate as a measure of policy.[25]

D. *Vector Autoregressions*

Motivation.—Vector autoregressions are often used to estimate the effects of policy. It is therefore useful to embed our new measure of monetary policy shocks in a VAR so that we can compare our results more directly with those from earlier studies. VARs also have the advantage of controlling for the past behavior of all the variables in the system.

The interpretation of the impulse response functions from a VAR is complicated, however.[26] An impulse response function for output or prices to a monetary policy innovation reflects both the effect of the initial innovation and the effect of the predictable subsequent moves in the policy measure. In the case where

[25] The results of our various robustness checks in the regressions controlling for commodity prices are very similar to the results of our baseline specifications. For this reason, we do not detail the results of the individual robustness checks. We also do the experiment of adding world commodity prices to the regressions using the intermediate broader measures of policy. The results for these regressions are similar to those using the actual funds rate.

[26] This point is discussed by John H. Cochrane (1998).

only unanticipated changes affect output or prices, the impulse response function simply shows the impact of the innovation. But anticipated movements in interest rates almost surely affect output and prices. For example, the response of output to a surprise change in our measure would surely be different if a surprise change were typically followed quickly by additional shifts in policy in the same direction than if it were typically followed by large offsetting policy moves. Similarly, no reasonable model implies that prices do not respond to forecastable policy changes. Thus, what the VAR impulse response functions capture are the combined effects of the initial innovation and the later policy moves that are forecastable based on the innovation.

VARs Using Our New Measure of Monetary Policy Shocks.—The specific VAR we consider is a variant of the one examined by Christiano et al. (1996). Our basic VAR has three variables: the log of industrial production, the log of the PPI for finished goods, and a measure of monetary policy. Following Christiano et al., we also consider a VAR that adds commodity prices. Throughout, we use Christiano et al.'s recursive identification strategy: monetary policy is assumed to respond to, but not to affect, the other variables contemporaneously. Christiano et al.'s VAR includes only a year of lags. Thus, monetary policy is not allowed to have any direct impact on the economy at horizons beyond a year. Since this assumption is very strong and highly questionable, we do not impose it. Instead, we include three years of lags in our baseline specification.

Our key difference from Christiano et al. is our measure of monetary policy. Our basic specification employs our new measure of policy shocks, whereas Christiano et al. use the actual funds rate. Since standard VARs enter the federal funds rate in levels, we cumulate our shock to produce a comparable series.

Figure 9 shows the response of the cumulated shock, output, and the price level to a one-percentage-point innovation in the shock, together with the one-standard-error bands. The top panel shows that the cumulated shock falls to about half its initial level after about a year and is then fairly flat. Thus the experiment considered here involves a less persistent change than the permanent, one-time shock considered above.

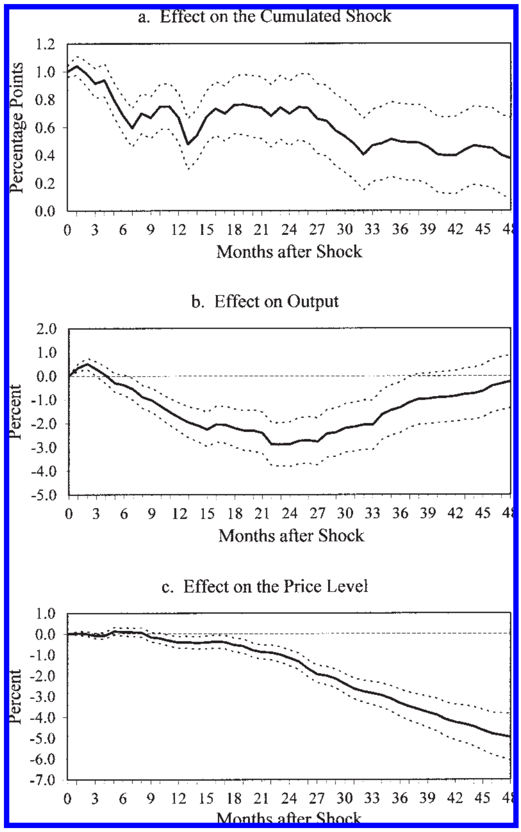

FIGURE 9. THE EFFECT OF MONETARY POLICY IN A VAR USING THE NEW MEASURE OF MONETARY POLICY SHOCKS

The other two panels of the figure show that the responses of output and prices are broadly similar to those we found in the simple regressions reported above. Output rises by a small amount for the first two months, then falls sharply through month 23, and then returns toward its initial level. The maximum *t*-statistic is over 3. For output, the main difference from our earlier findings is that the estimated effect is smaller. For example, the peak effect is 2.9 percent here, as opposed to 4.3 percent in the single-equation regression. Presumably this reflects the fact that in the experiment considered here, a substantial part of the interest rate movement is undone quickly. Also, output returns essentially all the way to its initial level here, as opposed to two-thirds of the way in the earlier results.

The response of prices implied by the VAR is small, irregular, and insignificant for eight months, and then negative. The monetary policy innovation lowers the price level by 0.5 percent after 18 months, 2.4 percent after 30, and 5.0 percent after 48. The *t*-statistic reaches 2 in month 20, 3 in month 24, and 4 in month 26. This response is somewhat faster than we found in our simple regression, where the price level was essentially unaffected until almost two years had passed.[27]

The effects of adding commodity prices to the system are similar to those of adding them to the baseline regressions. There are no major changes in the patterns or magnitudes of the responses of output and the price level to an innovation in the policy measure. The estimated output effects become somewhat smaller, peaking at -1.9 percent after 22 months ($t = 2.7$); and the estimated price effects also fall somewhat, reaching -3.8 percent after 48 months ($t = 4.5$).

VARs Using a Broader Measure of Monetary Policy.—We also estimate the VAR using the actual funds rate as the indicator of monetary policy. The estimated impact of policy on output is much slower and smaller than with our measure. And the price puzzle reemerges strongly: the price level does not fall below its initial level until about two years after the shock. This supports our earlier conclusion that the actual funds rate is contaminated by endogeneity and responses to anticipated economic developments.

As in other VARs, adding commodity prices to the system using the actual funds rate largely eliminates the price puzzle. There is now never any noticeable rise in the price level following an interest rate innovation; the peak effect is $+0.1$ percent after seven months. Crucially, however, the fall is dramatically weaker than with our new measure. For example, the effect of a monetary shock on the price level after 48 months is -0.5 percent using the actual funds rate, as opposed to -3.8 percent using our new measure. Similarly, the output effects remain much smaller than with our measure. The maximum effect of a shock on industrial production is -0.9 percent using the actual funds rate, and -1.9 percent using our measure. This suggests once again that including commodity prices is only a partial solution to the problem of forward-looking policy-making.

The VARs estimated using our new measure suggest larger but not faster output effects of monetary policy than found in previous VAR studies. Sims (1992), Christiano et al. (1996), and Bernanke and Mihov (1998), using VARs with broad policy measures and controlling for commodity prices, all find that output begins falling three to six months after a shock. This is similar to what we find using our new measure. Sims estimates a maximum impact of a one-percentage-point innovation in the funds rate on industrial production of about 1.5 percent, and Bernanke and Mihov and Christiano et al. find a maximum effect on real GDP of slightly less than 1 percent. In contrast, the VARs using our new measure suggest a maximum impact on industrial production of 2 to 3 percent. Thus, our results suggest that monetary policy has a larger impact on output than traditionally believed.

For prices, VARs estimated using our new measure suggest effects that are both much larger and much faster than previous estimates. Sims, Christiano et al., and Bernanke and Mihov find that when commodity prices are controlled for, a one-percentage-point innovation in the funds rate has little effect on prices for about a year and a half, and then causes a decline of 1 to 2 percent over the next few years. But the VARs with our new measure suggest a much stronger response: the price effect is consistently negative after six months when commodity prices are controlled for and after nine months when they are not, and the

[27] Restricting the number of lags, as Christiano et al. do, has mixed effects. When we reestimate our VAR with only one year of lags, the estimated response of output to a policy shock tracks the response with three years of lags closely for a year, but then diverges. The response peaks at -1.5 percent after 12 months. Reducing the number of lags has a smaller effect on the estimated response of prices, though again the estimated impact is smaller when fewer lags are included. These findings suggest that the true response of output and prices to monetary policy is quite drawn out, and that forcing the direct effects to be zero after a year leads to underestimates of the effects of policy.

price level is roughly 4 to 5 percent lower after four years.[28]

III. Conclusion

Determining how monetary policy affects the economy is critically important both for distinguishing between competing theories of fluctuations and for conducting policy. Unfortunately for economists interested in estimating the effects of policy, monetary policy is not conducted as a randomized experiment. There is no unique instrument of policy, such as the federal funds rate, that the Federal Reserve always focuses on. As a result, any candidate measure of policy sometimes moves in response to outside economic developments rather than to decisions by the Federal Reserve. More importantly, in deciding how to move its instruments, the Federal Reserve considers a tremendous amount of information about likely future movements in macroeconomic variables. As a result, measures of policy are likely to include many anticipatory movements. Because of these problems with conventional policy measures, estimating the effects of policy is extremely difficult.

To derive more accurate estimates of the effects of policy, this paper proposes and implements a new method for isolating monetary policy shocks. Our approach considers only changes in the federal funds rate that are the result of deliberate decisions by the Federal Reserve made at meetings for which there is a forecast prepared by the staff. We then remove the portions of these moves in the intended funds rate that represent the Federal Reserve's usual response to the forecasts. The resulting series should be largely free of interest rate movements that are either endogenous responses to economic developments or attempts by policy makers to counteract likely future developments. The movements in output and inflation in the wake of our new measure of monetary shocks should therefore reflect the impact of monetary policy, and not other factors.

Estimates of the effects of policy using the new shock series indicate that monetary policy has large and statistically significant effects on real output. In our baseline specification, a shock of one percentage point starts to reduce industrial production after five months, with a maximum fall of 4.3 percent after two years. The peak effect is highly statistically significant. For prices, we find that the one-percentage-point shock has little effect for almost two years, but then lowers the inflation rate by 2 to 3 percentage points. As a result, the price level is about 6 percent lower after four years. This estimate is overwhelmingly significant. The results for both output and prices are quite robust to variations in sample periods, control variables, specification, and the particular regression used to form our shock measure. The results are also robust to the measure of prices used. The most important uncertainty concerns the lag in the impact of policy on prices: in some specifications, the price level begins falling within six months after the policy shock, while in others it is unchanged for as much as 22 months.

Qualitatively, our findings are very consistent with textbook views of the effects of monetary policy. Contractionary monetary policy reduces both output and inflation. Both effects occur with a lag, with output moving before inflation. Quantitatively, the results suggest that the lags in the output effects are fairly short, while the lags in the inflation effects are harder to determine. More importantly, the results indicate that the impacts of monetary policy on both output and inflation are large.

[28] Our finding of larger price effects than earlier studies appears to be due partly to our focus on the PPI for finished goods. However, when we use the alternative price series, the effect after four years is slightly under 3 percent, which is still substantially larger than previous work has found. As before, the results of our robustness exercises in the VARs are similar to the results of the robustness exercises in the univariate regressions. We also estimate the VARs using the intermediate broader measures of policy. The results are qualitatively similar to those when the VAR is estimated using the actual funds rate.

TABLE A1—CHANGES IN INTENDED FEDERAL FUNDS RATE AT FOMC MEETINGS

Meeting date	Initial intended rate (percent)	Change in intended rate (percent)	Meeting date	Initial intended rate (percent)	Change in intended rate (percent)	Meeting date	Initial intended rate (percent)	Change in intended rate (percent)
1/14/69	6.4375	0.0000	6/19/73	8.5000	0.5000	3/21/78	6.7500	0.0000
2/4/69	6.4375	0.0000	7/17/73	9.7500	0.2500	4/18/78	6.7500	0.2500
3/4/69	6.7500	−0.1250	8/21/73	10.5000	0.2500	5/16/78	7.3125	0.1875
4/1/69	6.7500	0.5000	9/18/73	10.7500	−0.3750	6/20/78	7.5000	0.2500
4/29/69	7.6875	0.2500	10/16/73	10.5000	−0.7500	7/18/78	7.7500	0.1250
5/27/69	8.5000	0.1250	11/20/73	10.1250	0.0000	8/15/78	7.8750	0.1250
6/24/69	9.0000	0.0000	12/18/73	10.2500	−0.6250	9/19/78	8.3750	0.1250
7/15/69	9.0000	0.1250	1/22/74	9.7500	−0.3750	10/17/78	8.7500	0.2500
8/12/69	9.5000	0.2500	2/20/74	9.0000	−0.1250	11/21/78	9.6875	0.1875
9/9/69	9.0000	0.0000	3/19/74	9.1875	0.6875	12/19/78	9.8750	0.1875
10/7/69	9.1250	0.0000	4/16/74	9.8750	0.6250	2/6/79	10.0625	0.0000
10/28/69	9.1250	0.0000	5/21/74	11.0000	0.3750	3/20/79	10.0625	0.0000
11/25/69	9.1250	0.0000	6/18/74	11.6250	0.2500	4/17/79	10.0625	0.0000
12/16/69	9.0000	0.0000	7/16/74	12.7500	−0.5000	5/22/79	10.2500	0.0000
1/15/70	9.0000	−0.2500	8/20/74	12.2500	−0.3750	7/11/79	10.2500	0.0000
2/10/70	9.1250	−0.5000	9/10/74	11.7500	−0.6250	8/14/79	10.6250	0.3750
3/10/70	8.3125	−0.1875	10/15/74	10.4375	−0.8125	9/18/79	11.3750	0.1250
4/7/70	7.7500	0.0000	11/19/74	9.5000	−0.2500	10/6/79	11.5000	3.0000
5/5/70	8.2500	0.1250	12/17/74	8.8750	−0.6250	11/20/79	13.5000	0.0000
5/26/70	8.0000	0.0000	1/21/75	7.2500	−0.5625	1/9/80	13.5000	0.0000
6/23/70	7.8750	−0.2500	2/19/75	6.2500	−0.5000	2/5/80	13.5000	0.5000
7/21/70	7.3125	−0.2500	3/18/75	5.7500	−0.5000	3/18/80	16.5000	1.7500
8/18/70	6.7500	−0.5000	4/15/75	5.5000	−0.1250	4/22/80	18.3750	−3.8750
9/15/70	6.3750	−0.1875	5/20/75	5.1250	0.0000	5/20/80	10.8750	−1.3750
10/20/70	6.2500	−0.1250	6/17/75	5.2500	0.3750	7/9/80	9.3750	0.0000
11/17/70	5.7500	−0.6250	7/15/75	6.0000	0.1250	8/12/80	9.6250	0.2500
12/15/70	5.1250	−0.3750	8/19/75	6.1875	0.0000	9/16/80	10.2500	1.0000
1/12/71	4.5000	−0.5000	9/16/75	6.1250	0.2500	10/21/80	12.1250	1.5000
2/9/71	3.7500	−0.1250	10/21/75	5.7500	−0.2500	11/18/80	14.5000	1.7500
3/9/71	3.5000	0.1250	11/18/75	5.2500	−0.2500	12/19/80	18.7500	−0.7500
4/6/71	3.7500	0.3750	12/16/75	5.2500	0.0000	2/3/81	17.5000	−0.5000
5/11/71	4.2500	0.2500	1/20/76	4.7500	0.0000	3/31/81	15.0000	0.8750
6/8/71	4.7500	0.3750	2/18/76	4.7500	0.0000	5/18/81	18.5000	1.5000
6/29/71	5.1250	0.2500	3/16/76	4.7500	0.0000	7/7/81	18.5000	−1.0000
7/27/71	5.5000	0.1250	4/20/76	4.7500	0.1250	8/18/81	18.0000	−0.5000
8/24/71	5.6250	0.0000	5/18/76	5.1250	0.2500	10/6/81	15.5000	−1.0000
9/21/71	5.5000	−0.2500	6/22/76	5.5000	0.0000	11/17/81	13.5000	−1.0000
10/19/71	5.1875	−0.1250	7/20/76	5.2500	0.0000	12/22/81	12.1250	−0.2500
11/16/71	4.7500	−0.3750	8/17/76	5.2500	0.0000	2/2/82	14.0000	0.5000
12/14/71	4.3750	−0.6250	9/21/76	5.2500	0.0000	3/30/82	14.7500	−0.5000
1/11/72	3.6250	−0.3125	10/19/76	5.0000	−0.1250	5/18/82	14.0000	−0.7500
2/15/72	3.2500	0.0000	11/16/76	5.0000	−0.2500	7/1/82	14.0000	−0.5000
3/21/72	3.9375	0.3125	12/21/76	4.6875	−0.0625	8/24/82	10.2500	−0.7500
4/18/72	4.2500	0.1250	1/18/77	4.6250	0.0625	10/5/82	10.2500	−0.7500
5/23/72	4.2500	0.3125	2/15/77	4.6875	0.0000	11/16/82	9.5000	−0.5000
6/20/72	4.4375	0.1250	3/15/77	4.6875	0.0000	12/21/82	8.5000	0.0000
7/18/72	4.6250	0.0000	4/19/77	4.6875	0.1250	2/9/83	8.5000	0.0000
8/15/72	4.7500	0.1250	5/17/77	5.2500	0.1250	3/29/83	8.5000	0.1250
9/19/72	5.0000	0.1875	6/21/77	5.3750	0.0000	5/24/83	8.6250	0.2500
10/17/72	5.0625	0.1250	7/19/77	5.3750	0.0000	7/13/83	9.0625	0.3125
11/21/72	5.0625	0.1250	8/16/77	5.8750	0.1250	8/23/83	9.5625	−0.0625
12/19/72	5.3750	0.2500	9/20/77	6.1250	0.1250	10/4/83	9.3750	0.0000
1/16/73	5.7500	0.5000	10/18/77	6.5000	0.0000	11/15/83	9.3750	0.0000
2/13/73	6.3750	0.3125	11/15/77	6.5000	0.0000	12/20/83	9.5000	0.1250
3/20/73	7.0000	0.1250	12/20/77	6.5000	0.0000	1/31/84	9.3750	0.0000
4/17/73	7.0000	0.1875	1/17/78	6.7500	0.0000	3/27/84	10.1250	0.3750
5/15/73	7.5000	0.5000	2/28/78	6.7500	0.0000	5/22/84	10.5000	0.0000

TABLE A1—*Continued.*

Meeting date	Initial intended rate (percent)	Change in intended rate (percent)	Meeting date	Initial intended rate (percent)	Change in intended rate (percent)	Meeting date	Initial intended rate (percent)	Change in intended rate (percent)
7/17/84	11.0000	0.3750	9/20/88	8.1250	0.0000	12/22/92	3.0000	0.0000
8/21/84	11.5625	−0.0625	11/1/88	8.2500	0.0000	2/3/93	3.0000	0.0000
10/2/84	11.2500	−0.3750	12/14/88	8.4375	0.5625	3/23/93	3.0000	0.0000
11/7/84	10.0000	−0.7500	2/8/89	9.0000	0.1875	5/18/93	3.0000	0.1250
12/18/84	8.7500	−0.6250	3/28/89	9.7500	0.1250	7/7/93	3.0000	0.0000
2/13/85	8.5000	0.0000	5/16/89	9.8125	0.0000	8/17/93	3.0000	0.0000
3/26/85	8.5000	0.0000	7/6/89	9.5625	−0.2500	9/21/93	3.0000	0.0000
5/21/85	8.1250	−0.3750	8/22/89	9.0625	0.0000	11/16/93	3.0000	0.0000
7/10/85	7.6250	0.0000	10/3/89	9.0000	0.0000	12/21/93	3.0000	0.0000
8/20/85	7.8125	0.0000	11/14/89	8.5000	0.0000	2/4/94	3.0000	0.2500
10/1/85	7.8750	0.0000	12/19/89	8.5000	−0.2500	3/22/94	3.2500	0.2500
11/5/85	8.0000	−0.0625	2/7/90	8.2500	0.0000	5/17/94	3.7500	0.5000
12/17/85	7.9375	−0.1875	3/27/90	8.2500	0.0000	7/6/94	4.2500	0.0000
2/12/86	7.8125	0.0000	5/15/90	8.2500	0.0000	8/16/94	4.2500	0.5000
4/1/86	7.3750	0.0000	7/3/90	8.2500	−0.2500	9/27/94	4.7500	0.1250
5/20/86	6.8750	0.0000	8/21/90	8.0000	0.0000	11/15/94	4.7500	0.7500
7/9/86	6.8750	−0.5000	10/2/90	8.0000	−0.2500	12/20/94	5.5000	0.0000
8/19/86	6.3125	−0.3750	11/13/90	7.7500	−0.2500	2/1/95	5.5000	0.5000
9/23/86	5.8750	0.0000	12/18/90	7.2500	−0.2500	3/28/95	6.0000	0.0000
11/5/86	5.8750	0.0000	2/6/91	6.7500	−0.5000	5/23/95	6.0000	0.0000
12/16/86	6.0000	0.0000	3/26/91	6.0000	0.0000	7/6/95	6.0000	−0.2500
2/12/87	6.0000	0.0000	5/14/91	5.7500	0.0000	8/22/95	5.7500	0.0000
3/31/87	6.0625	0.1875	7/3/91	5.7500	0.0000	9/26/95	5.7500	0.0000
5/19/87	6.5000	0.2500	8/20/91	5.5000	0.0000	11/15/95	5.7500	0.0000
7/7/87	6.7500	0.0000	10/1/91	5.2500	0.0000	12/19/95	5.7500	−0.2500
8/18/87	6.6250	0.0000	11/5/91	5.2500	−0.5000	1/31/96	5.5000	−0.2500
9/22/87	7.2500	0.0000	12/17/91	4.5000	−0.2500	3/26/96	5.2500	0.0000
11/3/87	7.1250	−0.3125	2/5/92	4.0000	0.0000	5/21/96	5.2500	0.0000
12/16/87	6.8125	0.0000	3/31/92	4.0000	0.0000	7/3/96	5.2500	0.0000
2/10/88	6.6250	−0.1250	5/19/92	3.7500	0.0000	8/20/96	5.2500	0.0000
3/29/88	6.5000	0.2500	7/1/92	3.7500	−0.1250	9/24/96	5.2500	0.0000
5/17/88	7.0000	0.2500	8/18/92	3.2500	−0.1250	11/13/96	5.2500	0.0000
6/30/88	7.3750	0.2500	10/6/92	3.0000	−0.2500	12/17/96	5.2500	0.0000
8/16/88	8.1250	0.0000	11/17/92	3.0000	0.0000			

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