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The Lag from Monetary Policy Actions to Inflation: Friedman Revisited

by Nicoletta Batini and Edward Nelson

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Abstract

This paper updates and extends Friedman's (1972) evidence on the lag between monetary policy actions and the response of inflation. Our evidence is based on UK and US data for the period 1953–2001 on money growth rates, inflation, and interest rates, as well as annual data on money growth and inflation. We reaffirm Friedman's result that it takes over a year before monetary policy actions have their peak effect on inflation. This result has persisted despite numerous changes in monetary policy arrangements in both countries. Similarly, advances in information processing and in financial market sophistication do not appear to have substantially shortened the lag. The empirical evaluation of dynamic general equilibrium models needs to be extended to include an assessment of these models' ability to account for the monetary transmission lags found in the data.

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I. Introduction

At the Dec. 27–29, 1971, American Economic Association meetings, Milton Friedman (1972) presented a revision of his prior work on the lag in effect of monetary policy (e.g. Friedman 1961). His new conclusion was that 'monetary changes take much longer to affect prices than to affect output'; estimates of the money growth/CPI inflation relationship gave 'the highest correlation… [with] money leading twenty months for $M1$, and twenty-three months for $M2$' (p. 15).

In the intervening 30 years, new evidence has emerged in support of Friedman's estimate, so that it is now something of an international rule of thumb for countries that have experienced moderate inflation. Bernanke, Laubach, Mishkin, and Posen (1999, pp. 315–20) describe a two-year lag between policy actions and their main effect on inflation as 'a common estimate'. They observe that this estimate has been embodied in the forecasting and decision-making of several inflation-targeting central banks, and assume such a lag in their recommendation of an inflation target for the US. Gerlach and Svensson (2001) report that the European Central Bank has documented an approximate 18-month lag between money growth and inflation in the euro area.

A parallel development in recent years has been theoretical and empirical analysis of inflation dynamics. Several studies have modelled inflation behaviour with dynamic stochastic general equilibrium models. This has included empirical work on the New Keynesian Phillips curve (NKPC) (see e.g. Sbordone 1998; Galí and Gertler 1999). On the whole, this literature has concluded that postwar inflation in the US and several other countries can be successfully modelled using the NKPC, whose structure does not imply inherent persistence in inflation. In a recent contribution, Erceg and Levin (2001) (EL) support this view by arguing that the persistence in inflation observed in the US during its 'Great Inflation' period was not an intrinsic phenomenon; rather, it emerged from the interaction of firms' NKPC-style pricing behaviour and private sector uncertainty about the authorities' underlying inflation target. They argue that 'the [US] inflation rate exhibits much less persistence prior to 1965 and after about 1984' (EL, p. 3).[1]

[1] EL contend that inflation persistence diminished in the 1980s and 1990s because agents adjusted to the stabler Volcker-Greenspan monetary policy regime. See also Cogley and Sargent (2001).

Thus, many countries have moved toward inflation-targeting procedures that take inertia in inflation for granted, but formal modelling is moving toward specifications in which inflation persistence is not a structural, policy-invariant feature of the data. Can these two trends be reconciled? Or have the additional three decades of data overturned Friedman's finding of a lag between monetary actions and inflation?

II. Three Types of Inflation Persistence

To clarify discussion, it is useful to distinguish between three types of inflation persistence: (1) positive serial correlation in inflation; (2) lags between *systematic* monetary policy actions and their (peak) effect on inflation;[2] and (3) lagged responses of inflation to non-systematic policy actions (i.e. policy shocks).

Evidence on the first type of persistence is provided in Table 1, in the form of univariate representations of monthly CPI inflation (Δp) since 1965 for both the UK and the US.[3] We present a regression of Δp on a constant as well as a first-order autoregression for Δp. The regression on a constant provides useful summary statistics: its estimated parameter corresponds to the sample mean of inflation, while the residual standard error corresponds to inflation's standard deviation. The AR(1) specification for Δp summarizes the degree of type 1 inflation persistence, with the estimated autoregressive parameter indicating the serial correlation of inflation in the data.

For the US, the regressions are estimated over the sub-samples January 1965–December 1984 and January 1985–August 2001, a sample split suggested by Erceg and Levin's observations above. For the UK, we break the sample into January 1965–September 1992 and November 1992–August 2001, a split suggested by the shift to inflation targeting in October 1992. The decline in the serial correlation of US inflation, noted using quarterly data by EL, Cogley and Sargent (2001), Taylor

[2] Systematic policy actions refer to the portion of the monetary policy reaction function that consists of time-invariant responses to private sector shocks. They need not coincide with *anticipated* policy actions if policy responds to contemporaneous non-policy shocks.

[3] In this paper we will use the notation Δp to denote the seasonally adjusted monthly percentage change (expressed in annualized units) in the CPI, with π denoting annual inflation, i.e. the percentage change in the CPI on a year earlier. For the UK, the CPI measure used is the Retail Price Index (RPI) series, spliced at 1974 into the series RPIX that excludes mortgage interest costs. As prices are only available in not-seasonally-adjusted form for the UK, we seasonally adjust via seasonal dummies to generate a Δp series.

(2000), and others, is apparent in the monthly CPI data, with the AR(1) coefficient for inflation declining from over 0.6 before 1985, to below 0.4. For the UK, the decline in the autoregressive coefficient is even more dramatic: from about 0.5 before 1992, to insignificantly different from zero. This fall is in line with Kuttner and Posen's (2001) finding that explicit inflation-targeting countries such as the UK have experienced a 'large, significant reduction' in the autoregressive coefficient for monthly inflation.

In the past, the high serial correlation of inflation in postwar data has been used to motivate the use of Phillips curves that impose inherent inertia in inflation; see e.g. Fuhrer and Moore (1995). As type 1 inflation persistence has declined sharply, however, the empirical basis for assuming intrinsic inertia in inflation has weakened. On the other hand, the decline in type 1 inflation persistence was accompanied by sizable falls in both the mean and unconditional standard deviation of inflation (Table 1). Because of this, interest in the NKPC—which closely links inflation behaviour to the monetary policy regime—has gained momentum. Indeed, Erceg and Levin (2001) maintain that NKPC-type price-setting behaviour can account for the shift in the serial correlation of inflation observed in the US 'without relaxing the assumption of rational expectations or relying on arbitrary modifications [as in Fuhrer and Moore 1995] to the aggregate supply relation'. This is in keeping with the overall conclusion of the recent literature on the NKPC and its claim of success in accounting for type 1 inflation persistence.

Yet a model that accounts for type 1 persistence could fail to account for types 2 and 3 persistence. Of the three types of inflation persistence, accuracy of a model regarding type 2 is clearly most important for setting monetary policy. The degree of type 2 persistence is important because it determines the costs of a disinflation. As Friedman himself put it (1980, pp. 51, 60), 'A successful policy of reducing inflation will have as an unavoidable side-effect a temporary retardation of economic growth… The mechanism causing the contraction in output is the slowing of nominal spending in response to [monetary tightening] and the inevitable lags in the absorbtion of slower spending by wages and prices.' And after a country has successfully disinflated, knowledge of the lags in the effect of monetary policy is crucial for a successful inflation-targeting framework.

The standard NKPC, however, implies virtually no lag in effect of monetary policy actions on inflation—there is a strong immediate response of inflation to policy decisions. Consequently, additional model elements must be introduced to account for the lags (such as decision lags for price-setters in Rotemberg and Woodford 1997).[4] We discuss later some other features of the economy that could produce lags in the effect of monetary policy. When added to a macroeconomic model, such features do introduce delays in effect of both the systematic and non-systematic components of policy—types 2 and 3 inflation persistence. But in practice the only empirical evidence consulted by economic modellers, both in estimation and model testing, is on the effects of the policy-shock component—type 3 persistence.[5] For example, Rotemberg and Woodford set model parameters so as to match output and inflation responses to a policy shock.[6]

In fact, there are few theoretical or empirical grounds for believing that policy shocks represent either the most important source of macroeconomic variability, or that their estimated effects can help quantify the impact on inflation of the systematic monetary policy actions. Lucas (1972) provided a rationalization for effects of monetary shocks on output in flexible-price models, but never suggested that policy shocks were the most important source of output variability.[7] Similarly, schools of thought that rely on sticky prices to generate real effects of monetary policy, such as monetarism and New Keynesian economics, make no claim that monetary policy shocks dominate the business cycle. Rather, they maintain that, empirically, most real effects of monetary policy arise from the non-neutrality of policy responses to non-policy shocks (see Woodford 1998). Importantly, *no* theory asserts that only the non-systematic component of policy matters for inflation behaviour. In standard models, the monetary policy response governs whether a real shock that affects potential output has persistent effects on the output gap and inflation. The systematic component of policy is, consequently, crucial for inflation behaviour; arguably, monetary

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[4] Our simulations of the Erceg, Henderson, and Levin (2000) model suggest that supplementing the NKPC with nominal wage contracts does not produce a substantial lag between monetary policy actions and inflation.
[5] See Christiano, Eichenbaum, and Evans (1999) for a review of VAR evidence on the effects of monetary policy shocks.
[6] A similar estimation strategy is followed by Christiano, Eichenbaum, and Evans (2001).
[7] Indeed, Lucas's position is that for post-war US output fluctuations, 'the relative importance of technology and other real shocks is... something like 80%' (in McCallum 1999a, p. 284).

accommodation of real shocks was important in producing the ‘Great Inflation’ episode.

Current practice in model evaluation does not attach much weight to type 2 persistence, despite its relevance for policymaking. To aid future modelling, it would be useful to have some relatively model-free quantitative evidence on the extent of type 2 inflation persistence. We attempt to do so in this paper. Neither the selection of policy-stance measure for this purpose, nor the appropriate statistic to calculate, is a straightforward issue. Because the systematic component of policy is inherently endogenous, many of the familiar characteristics seen as desirable properties of measures of policy change, such as exogeneity, are inappropriate.

One possible approach is to undertake impulse response function analysis regarding the response of inflation to non-monetary shocks. The systematic component of policy consists of central banks’ responses to exogenous shocks arising from the private sector; and, as noted above, this policy reaction may heavily influence the ultimate response of inflation to private sector (and fiscal) shocks. A model can thus account for the relationship between inflation and systematic monetary policy actions, provided the model matches the response of inflation to all shocks hitting the economy. There are, however, practical obstacles to this approach to analyzing systematic monetary policy. As noted by Christiano, Eichenbaum, and Evans (1999, 2001) and McCallum (1999b), empirical work on impulse responses typically focuses on monetary policy shocks because there is considerably less agreement about the nature and effect of non-monetary shocks than there is about policy shocks (other than the recognition that non-monetary shocks account for the bulk of observed macroeconomic variability). Christiano, Eichenbaum, and Evans (2001, p. 4) observe that impulse response analysis of non-policy shocks requires ‘a stand on the nature of the non-monetary shocks... shocks to government spending, technology, ... preferences, etc.’, and argue that it is desirable ‘to learn about some aspects of the structure of the economy without taking a stand on these other shocks’. So impulse response-based analysis of systematic policy is vulnerable to mis-specification of the number, type, and relative importance of non-monetary shocks.

An alternative approach does not attempt to isolate the individual shocks affecting the economy, but instead exploits the fact that, in combination, these shocks generate a particular pattern of correlations between inflation and measures of monetary policy stance. Systematic monetary policy actions thus produce dynamic cross-correlations in the data—empirical regularities that a successful macroeconomic model should be able to match.[8] From this perspective, Friedman's empirical work on timing relations between monetary aggregates and inflation provides one such data regularity, which can be regarded as a measure of type 2 inflation persistence.

In this paper, we follow Friedman by using the correlation of inflation with money growth $k \geq 0$ periods earlier, a statistic denoted $r_{\pi\mu}(k)$, as one means of summarizing evidence on type 2 inflation persistence. In using monetary aggregates for this purpose, we take no stand on whether money has any special role in the transmission mechanism. Rather, we view money-growth rates as 'quantity-side' measures of the monetary conditions induced by central bank interest-rate policy. For example, open-market operations to alter short-term nominal interest rates tend also to change the growth rates of reserves and the money stock.[9] On the other hand, one concern is that changes in the opportunity cost of holding money not produced by current monetary policy—such as an increase in the own-rate on $M2$ after financial liberalization, or greater incentives for the private sector to hold purchasing power in the form of base money after a disinflation—potentially distort money growth. Our calculation of $r_{\pi\mu}(k)$ across sub-samples allows for changes in steady-state velocity growth due to these factors. Looseness in the money growth/inflation relationship should not be taken to imply the absence of a systematic lead/lag relationship. And the looseness of the relationship can be overstated; slower $M2$ growth in the US in the 1990s *was* followed by lower inflation. But in light of reservations about money growth, we also present correlations of inflation with Δr_t—the first difference of the short-term real Treasury bill rate—a variable chosen to capture the notion that monetary policy can

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[8] Policy shocks also contribute to the values observed for these correlations and other second moments of the data, but, as argued above, their contribution should be relatively minor in practice. In other words, the unconditional cross-correlations that we examine below are likely to be dominated by the mixture of conditional cross-correlations between monetary policy stance measures and inflation induced by non-monetary shocks, rather than by the conditional cross-correlations that arise from policy shocks.

[9] Furthermore, a fall in the 'natural' interest rate for a given setting of nominal interest rates tends to reduce money growth, as less money needs to be supplied to implement a given interest rate operating target. Again, in this case the money-growth movement accurately reflects the tighter conditions.

influence the real rate over short periods.[10] In addition, we report results using a term-structure based measure of monetary conditions.

Another concern in estimating dynamic relations between measures of systematic policy and inflation is that, if monetary policy adjusts completely and successfully to offset non-policy shocks, there should be no observed relation between policy measures and inflation. Several considerations, however, suggest that in practice such a relation will be present. Long-standing deviations of policymakers' specification of the economy from the true underlying economic process will tend to produce target misses that are attributable to policy actions.[11] Objectives other than deviations of inflation from target tend to make it optimal to move policy in such a way that persistent but temporary deviations from target occur.[12] And the variability in the precise lag in effect of policy means that some target misses will be due to prior policy decisions. For all these reasons, in an inflation-targeting regime, some systematic deviations of inflation from target will be associated with systematic policy actions.

III. Empirical Evidence

Table 2 presents, replicates, and updates the US timing evidence contained in Friedman's 1972 paper. He identified the cycles in nominal variables (measured by six-month growth rates in the CPI and money) associated with each cyclical peak and trough. For 1953–70, we largely confirm his finding of a one- to three-year lag between money growth and inflation. Most of the differences in our replication stem from our use of the adjusted monetary base and the current $M2$ definition as the two measures of money, compared with old $M1$ and $M2$ in his paper. Note that a clear

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[10] Use of Δr rather than the level of the real rate has the dual advantages that Δr behaviour is not dominated by the longer-term swings in the mean of r, which are likely determined by non-policy factors; and that cross-correlations with inflation are less affected by the arithmetic link between the real rate and future inflation from the Fisher relation. Our r_t series is the monthly average nominal bill rate minus an average of $E_t\Delta p_{t+1}$, $E_t\Delta p_{t+2}$, and $E_t\Delta p_{t+3}$. For both countries we study, the expectations $E_t(\bullet)$ are approximated by OLS projections of Δp_{t+i} on lags 1–12 of Δp_t and HP-filtered log industrial production (filter parameter 14400), plus dummies for price controls and indirect-tax changes. More details are provided in our data appendix, available on request.

[11] Prior to the 1970s, such specification errors might have included belief in a non-vertical Phillips curve and an overemphasis on 'special-factors' theories of inflation. More recently, a candidate for specification error is that the output-gap series used in policymaking is conceptually very different from the output gap that is used in the theory underlying the NKPC.

[12] In Rudebusch and Svensson (1999), for example, the policymakers' objective function penalizes volatility in inflation, the output gap, and interest rates.

lead for money over inflation (i.e., type 2 inflation persistence) exists in the pre-Great Inflation years 1953–64, a period that Erceg and Levin characterize as without type 1 inflation persistence. After 1971, the instability of the short-run Phillips curve became more evident and the US economy was hit by several supply shocks, so the link between business cycles and inflation loosened. For example, inflation continued to decline many years into the 1980s and 1990s expansions. Despite this break, for the full updated sample we find that money growth still leads inflation by well over a year; if anything, the lead of money growth over inflation is somewhat longer in recent decades, particularly when we use $M2$ growth.

Table 3 lists the maximum values of $r_{\pi\mu}(k)$ for 1953–2001 and selected sub-periods, using twelve-month growth rates of money and consumer prices. We report results for both the US and the UK. The results with the interest-rate-based measure of policy largely support the timing evidence using money growth.

Both for the period as a whole and for sub-samples, the US evidence suggests money leads inflation by over a year. For 1953–79, the lead is of the order of 12 to 30 months. The 1980–2001 data also suggest a long lead, with a peak of $r_{\pi\mu}(k)$ at $k = 23$ months for the base and 49 months for $M2$. For this period, however, the correlation coefficient itself is near zero using the base—largely reflecting the break in base velocity behaviour following the end of the Great Inflation and the onset of the Volcker-Greenspan regime. As Erceg and Levin argue, it took several years for agents to adjust to this regime change. The adjustment included a fall in average velocity growth, distorting the relation between inflation and prior monetary change for data that overlap the pre- and post-regime change period. This accounts for why the base growth/inflation correlation is near-zero when the 1980–85 observations are included, but becomes positive and significant for the last fifteen years of data (1986–2001), results for which we also report in the table. For the same reason, we have limited our examination of the relationship in the UK under inflation targeting to the last five years of data, which ensures that data on both money and inflation are generated within the inflation-targeting period.

A perhaps surprising feature of Table 3 is the resilience of the relationship between US inflation and prior $M2$ growth to changes in sample period. Most notably, the correlation remains sizeable, positive and significant even for sub-samples that completely exclude pre-1980 data. On the surface, this may appear inconsistent with the results of (Benjamin) Friedman and Kuttner (FK) (1992, Table 3). They find that the *F*-statistic for excluding *M*2 growth in an equation for GDP deflator inflation is not significant for 1960–90, and is particularly low and insignificant for samples beginning in 1970. While there are differences in inflation definition, precise sample period, and frequency of the data, we believe that these differences do not account for the apparent discrepancies between our Table 3 results and FK's. Rather, we believe that our results and FK are mutually compatible, for two reasons.

First, the multiple regression used by FK implicitly assumes a constant lag structure and constant steady-state velocity growth before and after 1980; while our computation of separate correlations for the post-1980 period allows for both a change in average velocity growth and a change in the average lag between money growth movements and inflation. The evidence in our Table 3 suggests that allowing for variation in the lag between *M*2 growth and inflation is important.

Second, FK evaluate the significance of money on the basis of the explanatory power it contributes to a regression after controlling for lagged inflation and lagged real GDP growth. By contrast, our correlations are based on the unconditional or bivariate relationship between inflation and prior money growth. Money growth may serve adequately as a simple summary measure of monetary policy stance, and may have a strong relationship with future inflation, yet provide no information content beyond that contained in real income growth and measures of excess demand. In particular, as discussed in Meyer and Varvares (1981, p. 24), Lipsey (2000, pp. 237–38), and Nelson (2001, Section 2.2), the proposition that inflation is a monetary phenomenon is fully consistent with the use of models in which money and other measures of monetary policy stance do not appear in the price-setting equations.[13] An eclectic view of the results, therefore, is that FK required money growth to have *extra* information about inflation not included in real activity measures—a stronger property of money than that demanded by standard models (which state that monetary policy only matters for inflation via its influence on aggregate demand) and our

[13] Thus we do not concur with Alvarez, Lucas, and Weber's (2001, p. 224) contention that the current use of New Keynesian models, which do not have monetary aggregates appearing explicitly, implies a rejection of the quantity theory.

results (which require only that money growth be a reasonable summary of monetary conditions).

For the UK, results for the 1953–79 period suggest a lead of money growth of 6 months over inflation—not negligible, but low compared to the values of k in the rest of Table 3. This reflects limitations of money base growth as a monetary indicator in the 1970s. The most significant monetary easing in the UK was a cut in reserve requirements in 1971, which presaged the take-off of inflation in 1972–75. Our UK base series is not adjusted for requirement changes and so misses this easing. Excluding the 1970s, Table 3 indicates a lead for UK money of 11 months for the pre-1980 period. Finally, the lead of money growth over UK inflation is found to be two years both for 1980–2001 as a whole and the last five years. The associated value of $r_{\pi\mu}(k)$ itself is large and significant for 1980–2001; much less so for 1996–2001, in part because of continued reaction by money-holders to the new UK policy regime, and in part because consumption has risen faster than output, with growth in transactions demand for money diverging from growth in nominal GDP or prices.

Bryan and Gavin (1994) argue that the lag between base growth and inflation is an artefact of the pre-1979 policy rule, and is absent from US data thereafter. Yet, as our tables show for both countries, while the money growth/inflation relation is looser after 1979, there remains a clear delay in the reaction of inflation. This suggests that, even if inflation persistence of the type 1 form is not invariant to the monetary policy rule, some inflation persistence of the type 2 form is part of the structure of the economy—at least for economies such as the US and the UK that have had moderate inflation—and is not an illusion generated by a particular policy rule.

Our results on lags are supportive of those presented by Friedman and Schwartz (1982) for the US and the UK. Friedman and Schwartz use data on M2, prices, and other variables for the century to 1975. They find for both economies that '[t]he response of prices...[to monetary change] is.. distributed over a long period...' (1982, p. 627) and report (1982, p. 412) a long-run one-for-one response of inflation to an increase in money growth, with most of the response completed within four years for both the US and the UK. Precise comparisons of the lag lengths we find for the two countries with those of Friedman and Schwartz are not possible because the data frequency used in Friedman and Schwartz's analysis is the cycle phase (an economic expansion or contraction), which averages 2–3 years. But our finding in Table 3 that the money growth/inflation correlation peaks with a lead for money of 1–4 years is consistent with their results.[14]

Table 4 checks the robustness of our results to the use of a different interest-rate-based measure of monetary policy, namely the spread of the nominal short-term interest rate over the nominal long-term interest rate. Galí, Gertler, and López-Salido (2001) argue that 'the yield spread may be thought of as a rough measure of the stance of monetary policy'. The expected relation between our yield spread measure and inflation is negative. For example, suppose the monetary authority attempts to peg the short-term interest rate in the face of expanding aggregate demand. The higher demand pressure will raise market-determined rates such as the long-term bond rate, and the spread of short rates over long rates will fall, correctly indicating a loosening of monetary conditions. Nevertheless, one can imagine circumstances where the spread changes even though the degree of excess demand in the economy is unchanged, so that term-structure-based measures become imperfect indicators of monetary stance.[15] Despite this caveat, the results in Table 4 for both countries do support our earlier findings. Movements in inflation take well over a year on average to follow movements in systematic monetary policy, and this result is robust to considering just the recent, non-inflationary monetary policy regimes in the US and the UK.

Table 5 reports evidence using annual monetary and inflation data for the two countries—for 1871–2000 for the US as well as post-war data, and 1835–2000 for the UK. It provides perhaps the most decisive evidence that the appreciable delay in the reaction of inflation to monetary changes is not a side-effect of a particular policy regime. Friedman (1961, p. 450) notes that the resilience of timing relationships between money and other variables 'under very different monetary arrangements' is evidence that those relationships are structural. His reasoning was that dynamic

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[14] The observations that Friedman and Schwartz (1982) make regarding dynamic reactions at the monthly and annual frequency are also consistent with the results in this paper. For example, Friedman and Schwartz (1982, p. 403) state that monetary change affects 'output after a brief lag (about six to nine months for the United States and the United Kingdom)... Later the impact shifts to prices (after about another fifteen to twenty months for the United States and the United Kingdom).'

[15] An additional complication for the UK is that up to the 1970s the authorities regarded the long-term government bond rate as an additional policy instrument rather than as a market rate.

relationships that prevail over a long span of data are unlikely to be attributable to a policy rule that was in force for only a small fraction of the sample. Table 5 shows that the 1871–2000 period is characterized by a one-year lead of $M2$ growth over US inflation, and similar results hold for 1948–2000. For the UK since 1835, base money growth leads inflation by one year, and this is robust to excluding the years most affected by wartime price control.[16] Given the drastic changes in monetary arrangements in both the US and the UK since the nineteenth century, we conclude that the existence of a lag of a year or more between monetary policy changes and their peak effect on inflation is a structural feature of both economies.

IV. Conclusions

Recent studies of inflation with dynamic general equilibrium models have emphasized the interaction of policy regime and the pricing behaviour of the private sector in producing empirical inflation persistence. While this may indeed be an important source of persistence that previous, non-optimizing models have neglected, we argue that there are strong grounds for believing that at least one type of inflation persistence is present in the data across many different policy regimes. This is the pronounced delay in the reaction of inflation to systematic monetary policy actions —a form of inflation persistence that appears to be very much still with us.

We find that the additional 30 years of data since the publication of Friedman (1972) continue to support his proposition that monetary policy actions take well over a year to have their maximum effect on inflation. This feature is present in data for both the US and the UK. In addition, we find generally consistent results across different measures of monetary policy, including those based on monetary aggregates. While our results are not inconsistent with findings that the money growth/inflation relationship has become weaker since 1979, we are able to recover significant relationships between inflation and money growth once the lags in the relationship are taken into account. This suggests that monetary aggregates can continue to have a useful role as one of a set of measures of monetary conditions.

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[16] Table 5 reaffirms Friedman's (1978) observation that '[i]n 1863, [W.S. Jevons] wrote: "An expansion of the currency occurs one or two years prior to a rise of prices." His finding has held ever since for both the UK and the US—of course not precisely, but on the average.'

The fact that we find lags to be a pervasive feature of the data has implications for the testing and development of macroeconomic models. The ability of models to match the observed serial correlation of inflation does not imply that they are able to account for all types of inflation persistence. It follows that the current methods used in the empirical evaluation of optimization-based models need to be extended to include an assessment of the models' ability to account for the lags in effect of systematic monetary policy actions.

For policymaking, our results are relevant to the question of whether innovations in financial markets in the last two decades, as well as the experience of the 'Great Inflation' of the 1970s, have changed the transmission mechanism of monetary policy in such a way that the lag between monetary policy actions and inflation has shortened. Thomas Sargent, for example, argued at a 1983 conference that 'the lag between monetary growth and inflation is getting shorter as private economic agents learn how to adjust their expectations to new information' (reported in Eguchi and Suzuki 1985, p. 4). Along these lines, former Reserve Bank of Australia Deputy Governor Stephen Grenville has noted that 'financial markets have become not only the transmission path of monetary policy, but are also... ready to sound the alarm should the authorities stray from the straight and narrow' (Grenville, 2001, p. 63), and FOMC member William McDonough has argued that '[t]here's no question that lags are [now] shorter' between Fed policy movements and the reaction of the economy (quoted in Temple-Raston, 2000).

An alternative view is that financial innovation is primarily relevant for the response of *financial asset prices* to monetary policy changes, and need not imply appreciable changes in the speed at which *goods market prices*, and thus inflation, react to policy movements. Indeed, as Welteke (2001) observes, to the extent that private agents become confident that the monetary policy regime will promote price stability, they may agree to arrangements in the goods and labour markets that leave them with less leeway to adjust prices in the short run. While, as discussed below, we have reservations about nominal contracts by themselves accounting for the lags in effect of policy, our results are indirectly supportive of Welteke's argument. In particular, they suggest that advances in information processing and in financial market sophistication have not, in fact, substantially shortened the lag between monetary policy actions and the reaction of inflation. Policymakers still need to take into account long delays between their actions and the reaction of goods market prices, even though financial prices react rapidly to policy developments.

Finally, we offer some conjectures about the underlying sources of the lags that Friedman found in the data and that we have reaffirmed. Friedman's own rationalization (1980, p. 60) was that 'lags arise partly from the existence of long-term contracts and of legal obstacles to changes in prices and wages, partly from the persistence of inflationary expectations, and partly from other sources.' Our results give only mixed support for the importance of the specific sources of lags Friedman identified. The importance of 'persistence of inflationary expectations' as a source of lags is undermined by our finding that long lags between monetary policy actions and inflation have remained despite diminution in the serial correlation of inflation and so a diminution in the likely amount of inertia in inflationary expectations. 'Long-term contracts and legal obstacles to changes in prices and wages' are no doubt present, and may even have increased in importance. However, it seems unlikely that nominal contracts can rationalize lags of more than a year between policy actions and inflation, since most pricing contracts in the US and the UK are likely to be negotiated at least once a year.[17]

In light of these considerations, an important source of lags must be that firms, even when they do have the opportunity to alter prices after a monetary policy change, initially *do not find it optimal* to change them by a large amount. For this, sources of inertia besides nominal contracts must be present. These sources of inertia can help promote a sluggish inflation response by accounting for the observation that costs rise more slowly than output in response to monetary policy changes.[18] Among others, Christiano, Eichenbaum, and Evans (2001) rationalize this observation with a model in which variable capital utilization allows production to meet higher demand in the short run with little initial pressure on costs. They focus on how well their model can

[17] As noted above, our simulations of the model of Erceg, Henderson, and Levin (2000) indicated that the combination of nominal wage and price contracts could not by themselves account for a long lag in the effect of monetary policy.

[18] It is possible to augment the aggregate demand side of the benchmark New Keynesian model to account for the sluggish response of output to monetary policy changes (see e.g. Chari, Kehoe, and McGrattan 2000; Edge 2000, Fuhrer 2000). However, but these additional elements typically do little to help produce a sluggish inflation response: forward-looking price setters will incorporate expectations of future market conditions into their pricing decisions.

match the response of inflation to a monetary policy shock, but an important issue for future research is whether this type of model can account for the lagged reaction of inflation to systematic policy actions, which we have found to be such a pervasive feature of the data.

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Table 1: Regression Evidence on Type 1 Inflation Persistence

United States

Sample Period: January 1965–December 1984:

$$\underset{(0.003)}{\Delta p_t = 0.064}, R^2 = 0, SEE = 0.0431, DW = 0.75.$$

$$\Delta p_t = \underset{(0.004)}{0.024} + \underset{(0.051)}{0.626}\, \Delta p_{t-1}, R^2 = 0.391, SEE = 0.0337, DW = 2.42.$$

Sample Period: January 1985–August 2001:

$$\Delta p_t = \underset{(0.002)}{0.032}, R^2 = 0, SEE = 0.0227, DW = 1.26.$$

$$\Delta p_t = \underset{(0.003)}{0.020} + \underset{(0.066)}{0.369}\, \Delta p_{t-1}, R^2 = 0.135, SEE = 0.0212, DW = 1.98.$$

United Kingdom

Sample Period: January 1965–September 1992:

$$\Delta p_t = \underset{(0.005)}{0.088}, R^2 = 0, SEE = 0.0860, DW = 0.95.$$

$$\Delta p_t = \underset{(0.006)}{0.042} + \underset{(0.047)}{0.525}\, \Delta p_{t-1}, R^2 = 0.275, SEE = 0.0753, DW = 2.19.$$

Sample Period: November 1992–August 2001:

$$\Delta p_t = \underset{(0.002)}{0.027}, R^2 = 0, SEE = 0.0224, DW = 2.27.$$

$$\Delta p_t = \underset{(0.003)}{0.030} \underset{(0.096)}{-0.130}\, \Delta p_{t-1}, R^2 = 0.018, SEE = 0.0222, DW = 2.08.$$

Note: Standard errors in parentheses.

Table 2: Lead of Money Growth over Inflation in Postwar US Business Cycles

From Friedman (1972, p. 15)			Replication and update			
	Lead in months of				Lead in months of	
Reference date	*M*1	*M*2	Reference date	Inflation trough or peak	Adjusted monetary base	*M*2
	Troughs			*Troughs*		
8/54	13	13	5/54	10/54	10	11
4/58	11	31	4/58	6/61	13	30
2/61	17	25	2/61	5/63	38	39
5/67	6	2	5/67	5/67	7	7
11/70	17	17	11/70	8/72	30	28
			3/75	6/76	13	21
			7/80	—	—	—
			11/82	7/86	21	37
			3/91	4/98	26	41
	Peaks			*Peaks*		
7/53	19	19	7/53	9/53	9	21
7/57	17	17	8/57	4/58	17	11
5/60	22	26	4/60	10/60	15	16
11/66	4	4	11/66	10/66	10	10
11/69	10	12	12/69	2/70	14	14
			11/73	1/75	22	25
			1/80	3/80	21	38
			7/81	—	—	—
			7/90	11/90	34	51
			3/01	2/01	15	24

Note: Following Friedman, this table is based on six-month growth rates of all variables. Some lines are blank because we have treated Jan 80–Nov 82 as one long recession. We have followed Friedman's dating of the 1966–67 mini-recession, which is not designated a recession in the NBER official chronology.

Table 3: Correlations between CPI Inflation and Measures of Systematic Monetary Policy

Sample period	Monetary policy measure: twelve-month money growth Maximum value of $r_{\pi\mu}(k)$		Monetary policy measure: change in short real rate Max. neg. value of $r_{\pi\Delta r}(k)$
	United States		
	Adjusted money base	$M2$	
Feb 1953–Aug 2001	0.304 [a,b] (k = 23)	0.680 [a,b] (k = 35)	–0.031 (k = 25)
Feb 1953–Dec 1979	0.615 [a,b] (k = 12)	0.772 [a,b] (k = 30)	–0.044 (k = 17)
Jan 1980–Aug 2001	0.031 (k = 29)	0.737 [a,b] (k = 49)	–0.030 (k = 25)
Sep 1986–Aug 2001	0.426 [a,b] (k = 29)	0.706 [a,b] (k = 49)	–0.139 [a] (k = 10)
	United Kingdom		
	Money base		
Feb 1953–Aug 2001	0.698 [a,b] (k = 11)		–0.033 (k = 13)
Feb 1953–Dec 1969	0.422 [a,b] (k = 11)		–0.163 [a] (k = 9)
Feb 1953–Dec 1979	0.769 [a,b] (k = 6)		–0.097 [a] (k = 8)
Jan 1980–Aug 2001	0.797 [a,b] (k = 23)		–0.073 (k = 13)
Sep 1996–Aug 2001	0.254 [a] (k = 24)		–0.136 (k = 10)

Note: Inflation is twelve-month percent increase in CPI (US), RPI/RPIX (UK). Base money series adjusted for millennium bulge by interpolating between Nov 1999 and Feb 2000 observations. US base series is Anderson-Rasche (2000) domestic base series for 1965–99, spliced into St Louis series for pre-1965 and 2000 observations. US $M2$ series is adjusted for introduction of MMDAs in 1983; pre-1959 observations are obtained by splicing in Friedman-Schwartz (1970) old $M2$ series.

a. Significantly different from zero using conventional t-test.

b. Significantly different from zero using Newey-West (1987) t-test.

Table 4: Correlations Between CPI Inflation and Yield Spread

Sample period	Monetary policy measure: nominal Treasury bill rate minus long-term government bond rate Maximum neg. value of $r_{\pi,sp}(k)$
	United States
May 1954–Aug 2001	–0.145 [a] (k = 41)
May 1954–Dec 1979	–0.386 [a] (k = 32)
Jan 1980–Aug 2001	–0.147 [a] (k = 58)
Sep 1986–Aug 2001	–0.192 [a] (k = 41)
	United Kingdom
	Maximum neg. value of $r_{\pi,sp}(k)$
Feb 1953–Aug 2001	–0.407 [a,b] (k = 33)
Feb 1953–Dec 1969	–0.173 [a] (k = 38)
Feb 1953–Dec 1979	–0.562 [a,b] (k = 0)
Jan 1980–Aug 2001	–0.410 [a] (k = 35)
Sep 1996–Aug 2001	–0.839 [a,b] (k = 23)

Note: Table gives the most negative value of $r_{\pi,sp}(k)$, the correlation between annual inflation π and sp, the yield spread, k quarters earlier. The spread consists of the difference between monthly average values of the nominal Treasury bill rate and the 10-year nominal government bond rate (for the US) or the 20-year nominal government bond rate (for the UK).

a. Significantly different from zero using conventional t-test.

b. Significantly different from zero using Newey-West (1987) t-test.

Table 5: Evidence from Annual Data

Sample period	Monetary policy measure: money growth Maximum value of $r_{\pi\mu}(k)$	
	United States	
	Adjusted money base	$M2$
1871–2000, GDP deflator inflation	—	0.542 (k = 1 year)
1948–2000, CPI inflation	0.343 (k = 2 years)	0.574 (k = 3 years)
	United Kingdom	
	Money base	
1835–2000	0.607 (k = 1 year)	
1835–2000 excluding WWI and 1940–50	0.692 (k = 1 year)	

Note: Inflation and money growth are percent changes in annual averages of price indices and money stocks.
Sources:
US money data: Friedman and Schwartz (1970); Federal Reserve Bank of St. Louis.
US price data: Balke and Gordon (1986); Federal Reserve Bank of St. Louis.
UK money data: Huffman and Lothian (1980); Capie and Webber (1985); Bank of England.
UK price data: Goodhart (1999); Bank of England.