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Inflation Expectations, Uncertainty, the Phillips Curve, and Monetary Policy

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Inflation expectations play a central role in models of the Phillips curve. At long time horizons inflation expectations may reflect the credibility of a monetary authority's commitment to price stability. These observations highlight the importance of inflation expectations for monetary policy. These comments touch on three issues regarding inflation expectations:

- The evolving treatment of inflation expectations in empirical Phillips curve models;
- Three recent models of information imperfections and inflation expectations; and
- Potential policy implications of different models.

The discussion will highlight two points: while historical experience suggests an important role for some deviation from the most restricted form of rational expectations in inflation dynamics, it also shows that other aspects of sluggish price adjustment– such as nominal rigidities—are important. The available indicators of inflation expectations show that imperfect information regarding central bank intentions has been one source of inertia in the formation of inflation expectations.

[1] I would like to thank Andrew Levin for helping me think about the issues discussed in this paper, and Ben Johanssen and Jonathan Wright for providing assistance with data and figures. This note is a slightly revised version of comments to appear in the proceedings of the Federal Reserve Bank of Boston's 53rd Economic Conference *Understanding Inflation and the Implications for Monetary Policy: A Phillips Curve Retrospective*. The views expressed here are the author's, and do not reflect those of the Federal Reserve Board or its staff.

1. Inflation Expectations in the Phillips Curve

The Phillips curve has come a long way from its original 1958 specification. At the Federal Reserve Board's conference on empirical work on price determination held in 1970, the dominant paradigm was adaptive expectations (Eckstein 1972). Robert Lucas's contribution at this conference is stunningly familiar to a reader today in its approach and emphasis on rational expectations—the idea that agents form expectations optimally given their understanding of the economy and the information available to them (Lucas 1972).

The rational expectations revolution had two quite opposite effects on subsequent empirical research regarding inflation. One branch of the literature, exemplified in the early contributions by John Taylor (1980) and by Julio Rotemberg (1982), followed Lucas's suggestion closely and specified tightly parameterized models incorporating various types of nominal rigidities, which led to various restrictions on a system of equations that would allow econometric identification. Another branch responded to the broader criticism leveled by Christopher Sims (1980) that the types of schemes traditionally used for identification in reduced-form Phillips curves and other empirical research were fatally flawed—"incredible," to use the terminology Sims employed—and looked to develop empirical techniques that imposed fewer restrictions on the data. Both lines of research bore significant fruit: modern dynamic general equilibrium models, with a large number of frictions, fit U.S. macroeconomic data quite well (see, for instance, Smets and Wouters 2007; Edge, Kiley, and Laforte 2009), and the set of stylized facts gleaned from analyses of vector autoregressions with minimal identifying restrictions has had a profound impact on the way such dynamic general equilibrium models are

specified (see Christiano, Eichenbaum, and Evans 2005). However, it seems fair to say that the need for structural models to use when considering policy changes that represent significant departures from historically typical behavior implies the case may often be that tightly parameterized structural models will play an important role. This need for better predictive structural models is, at some level, troublesome. As someone actively involved in specifying relatively large and rich dynamic equilibrium models, my perspective is that the underlying assumptions used to achieve identification are clearly "incredible." For example, while the model developed in Edge, Kiley, and Laforte (2007) has been useful for analyzing various questions and show signs of good forecast performance (Edge, Kiley and Laforte 2008b, 2009), it includes a large number of frictions that at least some economists may view skeptically (such as habit formation in consumption, adjustment costs in investment and nominal prices, and so on). But making empirical progress sometimes requires that economists make incredible assumptions; subsequent research strives to remove the need for such assumptions.

One area where such research on nominal price and wage rigidities is already being enriched, and may result in more plausible models, is in relaxing the assumption that perfect and homogeneous information sets underly price-setting behavior, which has been the primary assumption since Taylor (1980) and Rotemberg (1982). It is interesting to note that Robert Lucas emphasized expectations that were rational subject to an information constraint—in his model presented at the Fed's 1970 conference and in

related work (Lucas 1972, 1973), agents in the economy only imperfectly perceived aggregate conditions.[2]

While research has found greater empirical support for the simple full-information rational-expectations model in recent data (for instance, see Kiley 2007), my reading of the evidence from the aggregate inflation dynamics literature suggests that some type of information constraint is needed to explain fluctuations in U.S. inflation over the past forty years. These stylized facts about postwar U.S. inflation are well known:

- Inflation seems to respond sluggishly to (some) aggregate disturbances (see Christiano, Eichenbaum, and Evans 2000)
- The costs of disinflation are sizable (see Ball 1994)
- Inflation dynamics seem well characterized by a Phillips curve in which both leads and lags of inflation are important, especially for data including the 1970s and early 1980s (Fuhrer and Moore 1995, Kiley 2007).

But these stylized facts provide little guidance regarding what types of information imperfections are important to help explain fluctuations in the U.S. inflation rate.

2. Models of Imperfect Information and Inflation Expectations

Imperfections in information, and how this may influence inflation expectations and the behavior of economic gagents, has been the subject of some research, which includes:

[2] A glance back at John Muth's (1961) article on rational expectations reveals that his idea was more in line with the information-constrained version of rational expectations: "The hypothesis can be rephrased a little more precisely as follows: that expectations of firms (or, more generally, the subjective probability distribution of outcomes) tend to be distributed, for the same information set, about the prediction of the theory (or the "objective" probability distributions of outcomes)" (Muth 1961, 316). In particular, Muth suggests that expectations are distributed around the mathematical expectation, implying some difference in signals available to different agents or errors in expectations.

- Learning about the structure of the economy (see Orphanides and Williams 2005, 2007)
- How imperfect information impacts upon the goals (or credibility) of the central bank (see Ball 1995, Bomfim et al. 1997, Erceg and Levin 2003, Kiley 2008)
- Understanding the costs or constraints on information acquisition or processing (Caballero 1989, Kiley 2000, 2007, Carroll 2003, Reis 2006a, 2006b, Sims 1998, 2003, 2006)

Interestingly, it is primarily the third example of imperfect information, which emphasizes the costs of acquiring or processing information, that gives rise to differences in information sets across agents, as emphasized in Lucas (1972, 1973).

Each of these theories is capable of explaining costly disinflations and providing evidence on inflation dynamics. To date, research has not compared the ability of each model to fit the data relative to the other models. I will focus my attention on two of these models: imperfect information regarding the inflation objective of the monetary authority, and models of costly information acquisition.

The idea behind models emphasizing imperfect information regarding the inflation objective is simple: in an environment where the inflation objective of the monetary authority is not explicit or widely known, households and firms will need to infer where the monetary authority intends to bring inflation from its policy actions. As a result, agents make persistent mistakes regarding the inflation objective during a transition period after the objective has shifted. This idea seems a plausible explanation of inflation dynamics. For example, the Federal Reserve did not reveal an explicit

objective for inflation in the period around 1980 when it began its effort to bring inflation down from undesirably high levels. And models incorporating imperfect information can explain many of the stylized facts regarding inflation dynamics, including the costs of the Volcker disinflation (see Erceg and Levin 2003) and the slow evolution of survey measures of long-run inflation expectations (Kiley 2007).

Models of costly information acquisition can also explain many of the stylized facts regarding inflation. Importantly, research in both the information processing tradition (such as Sims 1998, 2003, 2006) and in the information cost/infrequent updating tradition (for instance, Reis 2006a, 2006b) have emphasized that these models can explain the sluggishness of adjustment in much broader contexts—meaning that in addition to helping explain inflation, such models may help us better explain the observed patterns in consumption, investment, and other variables. The ability of such models to explain a range of facts is a great strength.

Christopher Sims's work on rational inattention is built upon an especially solid foundation: the communications literature has developed axiomatic descriptions of uncertainty and analyzed how constraints on information processing capacity affect choices regarding information flow. However, the payoff of applying this research to economic modeling has yet to be realized, as this area is very complex. The complexity of economic problems reflects their dynamic nature, the endogeneity of aggregate variables that can provide information, and the possibility of rich information "production functions."

Moreover, the information imperfections emphasized by Sims (2003, 2006) lie in how information is processed by economic agents. An added area of complexity in

economic problems involves the computation of optimal actions by firms and workers under uncertainty and with highly nonlinear objective functions and constraints. While the computational tools to solve such problems are well understood by economists for many simple parametric examples, it is not obvious that the costs of such computations are trivial to the economic agents making these decisions. Modeling approaches that emphasize such costs, and their impact on the form of decisions made by workers and firms, may prove just as valuable to further our understanding of wage and price behavior as the information-processing approach that has been the subject of research by Sims and others.[3]

Finally, I should also note that some recent research has suggested that a model in which inflation and other expectations reflect some type of information imperfection may be capable of explaining the data on prices without reference to nominal price rigidities. I think this is unlikely for at least three reasons. First, my own empirical work on the Phillips curve that compared some sticky price and sticky information models showed clear evidence supporting the sticky price specification (Kiley 2007). Second, my dissertation considered a model with endogenous price and information rigidities and showed that sticky price and imperfect information models implied different effects on the form of the Phillips curve from the trend inflation rate and the higher moments of inflation. Cross-country evidence clearly shows evidence of the link between mean inflation and the form of the Phillips curve, suggesting an important role for sticky prices (Kiley 2000). Finally, casual observation and microeconomic evidence supports a role

[3] Gabaix and Laibson (2000) present an example of this type of research. Their analysis is sufficiently distant from the form of a dynamic price adjustment problem that development of this type of reasoning to the problem of inflation dynamics is a substantial challenge, with unclear payoff.

for infrequent adjustment of nominal prices and wages in macroeconomic models (see Nakamura and Steinsson 2008). These considerations suggest that a model that combines a microeconomic foundation for nominal price rigidities with the costs of acquiring or processing information will best account for the micro- and macro-economic aspects of price adjustment that have been documented. Woodford (2008) presents a step in this direction.

3. Inflation Expectations and Monetary Policy

Given the model emphasizing imperfect information, I will turn to some of the implications this poses for policymakers' inflation objective.

In the United States, we have a few data sources regarding the long- horizon of inflation expectations; these sources are surveys of household and professional forecasters and measures of inflation compensation implied by yields on nominal and inflation-indexed Treasury securities. Models emphasizing imperfect information regarding the policymakers' inflation objective imply that these data should show a link between monetary policy actions or the policy regime and these long-horizon inflation expectations—as inflation expectations at long horizons should reflect, to a significant extent, the expectations of households and firms regarding the inflation objective. The data show such links in several areas.

The top panel of Figure 1 presents data on long-horizon inflation expectations from the Reuters/Michigan Survey of Households and the Survey of Professional Forecasters.[4] Long-horizon expectations from the Michigan Survey or from professional

[4] This survey was formerly conducted by the American Statistical Association (ASA) and the National Bureau of Economic Research (NBER) and was known as the ASA/NBER survey. The Federal Reserve Bank of Philadelphia, in cooperation with the NBER,

forecasters are sporadically available prior to the 1990s; both series are available continuously since the early 1990s. It is clear that long-horizon inflation expectations have fallen over the past two decades; the recent data arguably provide evidence of some degree of anchoring.

Kiley (2008) shows that the survey measures of long-horizon inflation expectations in the United States behave very much as implied by models emphasizing uncertainty regarding the central bank's inflation objective: long-horizon inflation expectations respond to policy actions that are deemed either restrictive or expansionary, as judged by deviations from the Taylor rule, and the quantitative magnitude of such responses is consistent with plausible specifications and estimates of the costs of disinflation. This relationship can be expressed graphically. I define the perceived tightness of monetary policy as the gap between the nominal federal funds rate (r(t)) and the level predicted by the following Taylor rule involving consumer price inflation (p(t)) (as measured by the CPI), a perceived inflation target measured by long-run inflation expectations from the Reuters/Michigan Survey (p*(t)), and the output gap (y(t))[5]

$$r(t) = 2 + p(t) + 0.5*(p(t)-p*(t)) + 0.5*y(t).$$

The bottom panel of Figure 1 plots the four-quarter change in the level of long-run expected inflation against this measure of perceived tightness of monetary policy lagged four quarters; there is a strong negative relationship.

Insert Figure 1 about here

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assumed responsibility for the survey in June 1990. With the exception of two observations, namely 1990:Q1 and 1991:Q2, the data from 1979 through 1991 are from the Blue Chip Survey. The two exceptions are from The Livingston Survey.

[5] From the Federal Reserve Board's FRB/US model.

Gurkaynak, Levin, and Swanson (2006) and Beechey, Johannsen, and Levin (2007) examine differences in the properties of measures of inflation compensation and inflation expectations between the United States and other countries that have explicit inflation objectives. Their analyses demonstrate that both survey measures of inflation expectations and inflation compensation implied by government-issued securities appear more stable in countries with an explicit inflation objective. Interestingly, there is pretty clear evidence that the dispersion in long-run expected inflation is much smaller in some inflation targeting countries. Figure 2 compares the dispersion in long-run expected inflation among professional forecasters for the euro area and the United States, following Beechey, Johannsen, and Levin (2007); dispersion is much lower in the euro area, which has an explicit long-run objective for inflation. This seems clearly consistent with a model emphasizing uncertainty regarding the long-run inflation objective as an important aspect of the link between monetary policy, expectations, and inflation or economic activity.

Insert Figure 2 about here

Finally, recent research has emphasized that inflation uncertainty is a significant factor determining term premia on nominal bonds (and hence the slope of the term structure; see Wright 2007). The link between the monetary policy regime and uncertainty about long-horizon inflation objectives suggests that the nature of such regimes can be expected to have significant effects on the term structure of interest rates. Figure 3 provides such an example. The Bank of England was given operational independence on May 6, 1997, and the slope the nominal yield curve flattened considerably that day, while the slope of the real yield curve changed very little.

Insert Figure 3 here

Taken together, I interpret the set of results illustrated in these three figures as suggesting that the setting of monetary policy and the nature of the policy regime are important determinants of inflation expectations and, potentially, macroeconomic performance more generally.

These concrete results provide an example of a type of analysis that cannot yet be supported by research in, for example, the rational-inattention vein. It may be, however, that these stylized facts are very consistent with a model of rational inattention. Given the potentially wide-ranging implications of such models for macroeconomic dynamics that have been tentatively suggested in previous work, I view research in this direction as very promising. In the meantime, I also think that research emphasizing particular stories that may be applicable to policy considerations in the short-to-medium run, like that motivated by the model of imperfect information regarding the inflation objective, is likely to have a direct impact on policy discussions.

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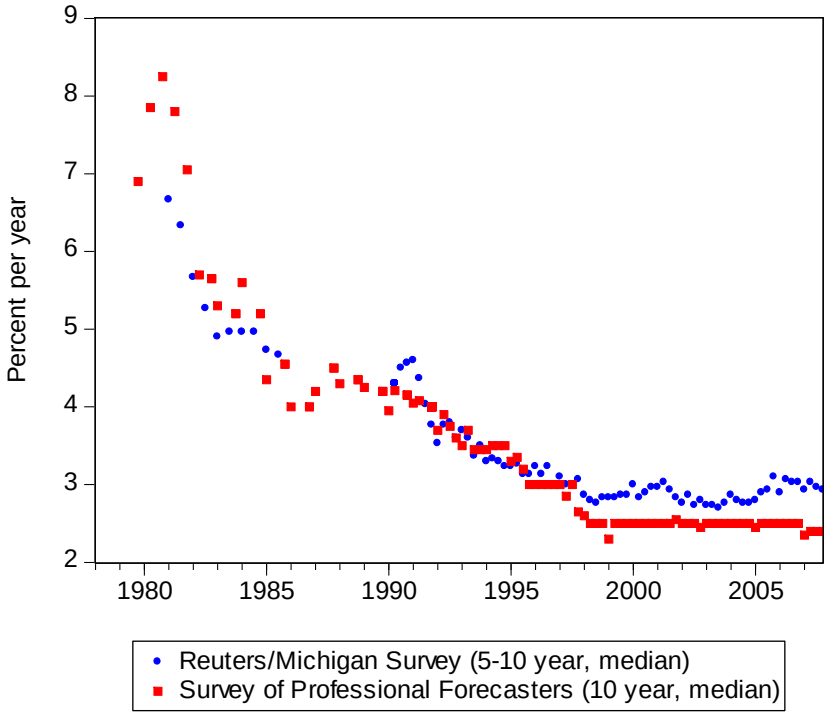
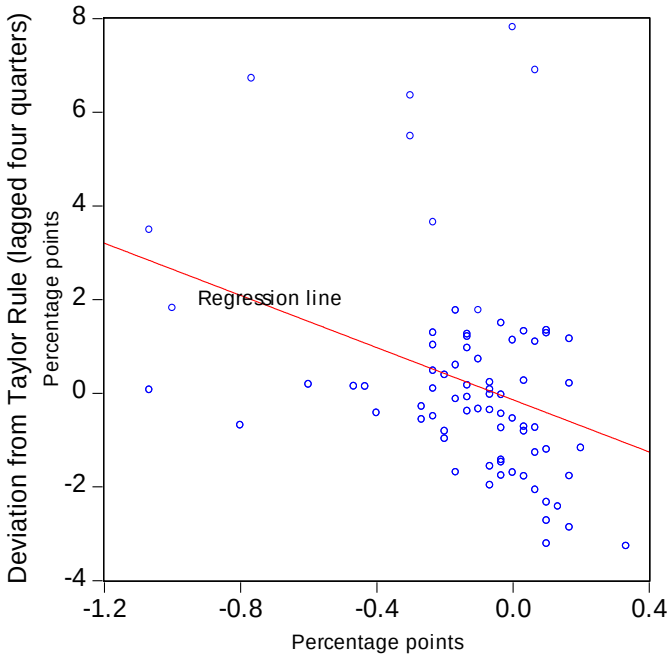
Figure 1
Panel A: Measures of Long-run Inflation Expectations



Panel B: Scatterplot of Change in Long-run Expectation Against Perceived Tightness of Monetary Policy



Four-Quarter Change in Long-run Expectation (Reuters/Michigan Survey, median)

Figure 2
Cross-Sectional Dispersion in Long-Run Inflation Expectations

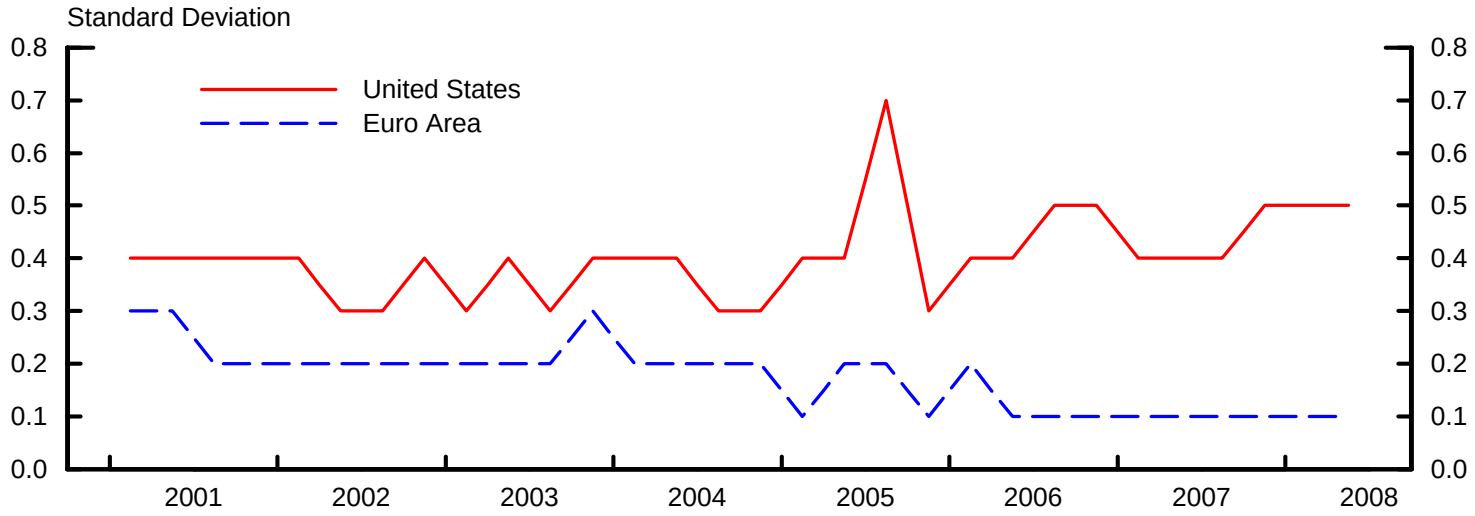


Figure 3
Nominal and Real Forward Curves in the United Kingdom Around Granting of Independence to the Bank of England