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**Modeling Inflation: A Policymaker's Perspective**

**Remarks by**

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**at the**

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Nothing is more important to the conduct of monetary policy than understanding and predicting inflation. Price stability is our responsibility as central banks--it is how, in the long run, we contribute to society's welfare. Achieving and maintaining price stability will be more efficient and effective the better we understand the causes of inflation and the dynamics of how it evolves.<sup>1</sup>

I think central bankers are asking more of inflation analysis these days. In the United States, our attention was focused for many years on containing and then reducing inflation. The risks and rewards were one-sided, and policymakers were mostly interested in whether inflation would rise. Now that we are in the neighborhood of price stability, we can be faced with looking at the possibility that inflation will fall too low as well as rise too high. Moreover, so long as inflation expectations are well anchored, we can tolerate limited changes in inflation, but we need to know that a rise or fall is not the beginning of a more extended trend. Consequently, we focus closely on the reasons for any changes in inflation and their implications for the outlook.

Of course, I have always known how important the analysis and forecasting of inflation was for monetary policy, but I must admit that as someone who now has to go on record with a vote on the basis of some notion of the future course of inflation, the exercise has taken on added meaning. I thought I might take advantage of this captive audience of researchers on central bank policies to ruminate a bit on the evolution of inflation modeling and suggest areas for further research. I know that European central

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<sup>1</sup> The views I am expressing today are my own and not necessarily those of my colleagues on the Federal Open Market Committee. John Roberts, of the Board's staff, helped with the preparation of these remarks.

banks have been in the forefront of recent efforts to improve our understanding of some key issues in this area, but I will focus on our practices in the United States.

### **The Stability of the Basic Framework**

I find it remarkable how fundamentally stable our basic framework for analyzing inflation has remained over the past thirty-five years or so: That basic framework is essentially the expectations-augmented Phillips curve introduced by Milton Friedman and Edmund Phelps in the late 1960s.<sup>2</sup>

One of the key assumptions underlying this basic framework is the temporary rigidity of wages and prices. It is because of these nominal rigidities that monetary shocks have real effects: In the well-known litany, wages and prices do not change immediately in response to a positive monetary surprise, so real interest rates fall, and spending is stimulated. But higher demand cannot be met without pushing firms up their marginal cost curves as they compete for scarce labor and other resources. As opportunities to raise prices present themselves, firms take them to better align prices with costs. That process may be gradual, because firms' competitors may not be raising their prices at the same time.

It is easy to see in this tale the central mechanism of the Phillips curve. What is missing from the story, though, is that seminal feature of Friedman and Phelps's framework, namely, expectations. Expectations are a key part of the framework because wages and prices will be set for some time, and so it is important for workers and firms to consider the economic conditions expected to prevail during the period that the wages

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<sup>2</sup> Milton Friedman (1968), "The Role of Monetary Policy," *American Economic Review*, vol. 58 (March), pp. 1-17; Edmund S. Phelps (1968), "Money-Wage Dynamics and Labor-Market Equilibrium," *Journal of Political Economy*, vol. 76 (July-August, part 2: Issues in Monetary Research), pp. 678-711.

and prices are fixed. If inflation is anticipated over the period ahead, wages and prices will be set commensurately higher as workers and firms strive to protect themselves against the erosion of their purchasing power.

As Friedman and Phelps emphasized, these efforts to protect against the erosion of purchasing power by inflation will mean that an ongoing and fully anticipated inflation will, to a first approximation, have no effect on the level of resource utilization; the outcome of the economy will be whatever the real forces at work dictate. Friedman called the unemployment rate determined by such real factors the natural rate of unemployment. An important implication of the expectations-augmented Phillips curve is that any attempt to use monetary policy to lower the unemployment rate below the natural rate on a sustained basis will end in failure. Initially, expansionary monetary policy would lower unemployment as well as raise inflation. As the stimulus continued, however, firms and workers would increasingly protect themselves against the higher inflation, giving an additional boost to inflation. Eventually, there would be no additional employment; only a (self-reinforcing) higher rate of inflation.

In 1970, the Federal Reserve held a conference that addressed this then-new framework; the conference encompassed both theoretical extensions, including Lucas' first exposition of rational expectations, and empirical implementation.<sup>3</sup> In its essentials, the way we forecast inflation today is not all that different from what came out of that conference. That is, inflation is importantly a function of an output or employment gap relative to a natural rate, plus some measure of inflation expectations.

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<sup>3</sup>*The Econometrics of Price Determination* (1972), proceedings of a conference sponsored by the Board of Governors of the Federal Reserve System and the Social Science Research Council, October 30-31, 1970 (Washington: Board of Governors of the Federal Reserve System).

## **Advances within the Basic Framework**

One of the first challenges that the new framework had to face was the supply shocks of the early 1970s. The framework was extended to allow for the effects of shifts in relative prices, such as crude oil and import prices. Such shifts can feed through fairly directly to the measures of core inflation through their effect on business costs, though their influence on inflation should be temporary unless they get built into labor costs or inflation expectations. We include these types of price terms today in our forecasting equations, and they are important to forming our views of the inflation outlook and thus to the policy process.

Another early development within the framework was the buttressing of its microeconomic foundations, in particular by paying more careful attention to the modeling of nominal rigidities. John Taylor's staggered-contracts framework remains a touchstone because of its intuitive appeal--annual wage reviews are a familiar experience for most people who work. Much subsequent work--including, recently, among economists at the European Central Bank and the euro-area national central banks--has confirmed the key assumption underlying this model, which is that wages and prices are changed infrequently.

A key objective of Taylor's staggered-contracts model was to show that, in an economy with nominal rigidities, monetary policy can have important effects even when expectations are perfectly rational. However, about a decade ago, Jeff Fuhrer and George Moore pointed out that inflation was more persistent than was predicted by the model

with sticky prices and rational expectations.<sup>4</sup> Since their work, a number of researchers have suggested that “sticky information” or rules of thumb can account for this excess persistence. Such departures of expectations from perfect rationality can be an important source of observed inflation dynamics.

At the Fed, the staff takes a number of different approaches to the modeling of expectations. The staff’s large, formal model (FRB/US) assumes rational expectations--but with a twist. In particular, the model addresses the Fuhrer-Moore critique by making inflation itself, as well as the levels of wages and prices, costly to adjust. The implications of these additional frictions are very similar to those of the departures of expectations from perfect rationality used by other modelers. An advantage of a model with expectations that are, at least in part, rational is that we can address questions related to how the behavior of the economy may change when the systematic implementation of monetary policy changes.

We also look at models that assume that inflation expectations are well modeled by lagged inflation--the original proposal of Friedman and of Phelps. Such models may not be as useful in addressing policy questions. However, they have a good forecasting track record.

### **The Performance of the Board Staff’s Inflation Forecast**

The Board staff forecasts distributed to the Federal Open Market Committee (FOMC) are judgmental: Although the staff consults a variety of models in coming up with its forecasts, no one model can be said to summarize the staff view. Also, the staff

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<sup>4</sup> Jeff Fuhrer and George Moore (1995), “Inflation Persistence,” *Quarterly Journal of Economics*, vol. 110 (February), pp. 127-59.

forecasts are not necessarily its best guess on how inflation will evolve; the forecasts are conditioned on an assumed path for monetary policy and, during some periods, at the behest of policymakers, the staff did not assume what it would have viewed as the most likely policy path.

I have distributed a figure that shows the Board staff's four-quarter-ahead forecasts for inflation as measured by the core Consumer Price Index along with the actual outcomes. The period shown is 1984 to 2000; I chose those years because the current definition of the core CPI did not come into use until 1983, and the staff's forecasts remain confidential for five years.

As shown in the inset box, the root-mean-squared error of the staff projections has been smaller than that of a naïve benchmark model, in which inflation is assumed to continue at its pace over the preceding four quarters. Nonetheless, the one-year-ahead root-mean-squared error of the staff forecast is about 1/2 percentage point. That is to say, almost one-third of the time, inflation has been either more than 1/2 percentage point higher, or more than 1/2 percentage point lower, than the staff has predicted. Moreover, over the period shown, there was, on average, some bias in the staff's inflation forecasts; inflation has tended to come in lower than the staff anticipated, by about 0.2 percentage point per year.

No single explanation suggests itself for either the extent of the misses or the bias. Rather, a variety of factors has caused inflation to deviate from expectations.<sup>5</sup> At times, demand was not as robust as anticipated, and unexpected but persistent changes in the

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<sup>5</sup> The discussion of the forecasting record that follows is largely a matter of conjecture and guesswork. It is hard to pinpoint the cause of any particular forecast error. I am drawing on my own memories of events, as well as those of current members of the Board's staff.

foreign exchange value of the dollar and oil prices fed through to core CPI inflation on several occasions. But I will concentrate on one general phenomenon and two episodes that help illustrate how our understanding has evolved and some of the more general challenges for inflation forecasting over the past twenty years.

One factor that may account for some of the upward bias over this entire period was a gradual reduction in the natural rate of unemployment. With hindsight, I believe we can point to a number of developments in labor markets that are consistent with such a reduction. For example, disability insurance rolls rose steadily over this period, which allowed many people who likely would have had above-average unemployment rates to withdraw from the labor force. Also, in the early 1990s, many public opinion surveys indicated a sharp increase in worker insecurity--and workers who are anxious about losing their jobs will be less willing to risk unemployment. These examples illustrate the need to be alert to the possibility of the natural rate shifting. As Friedman emphasized, the natural rate is not a rigid data point, but rather the reflection of many developments in the economy.

In the 1988-90 period, the behavior of crude oil prices, unemployment, and the exchange rate were not especially surprising or anomalous. However, the models the staff was consulting in preparing its forecasts may have been miscalibrated. In particular, inflation expectations perhaps were becoming better anchored, so that an unemployment rate below the natural rate was putting less pressure on inflation than it would have over the preceding twenty years. Likewise, the staff may have overestimated the ongoing effects of the dollar decline on inflation, as the models in use at that time inevitably gave

considerable weight to the experience of the 1970s. Empirical estimates unavoidably lag these sorts of endogenous changes in inflation dynamics.

For the period from 1996 to 1998, inflation also came in consistently lower than the staff forecast. Here, the pick up in structural productivity growth was the likely cause: The historical record suggests that a sustained acceleration in productivity affects prices before it affects wages. Thus, the pickup in productivity growth has a direct, depressing effect on costs--and thus ultimately on prices. It took Fed forecasters--and others--a while to discern the acceleration in productivity and its implications for inflation. Interestingly, by the time of the forecasts made in 1998 and 1999--the 1999 and 2000 observations on the chart--the string of forecasting errors had ended. This improved performance likely reflected the eventual recognition that productivity growth had increased on a sustained basis.

### **An Agenda for Further Research**

As I noted at the beginning of my remarks, research aimed at improving our understanding of and ability to predict inflation is essential to the central banker's mission. The better the forecasts, the better the odds that policy choices will contribute to economic stability and efficient resource allocation. Needless to say, more work remains to be done--and always will. My chart stops at 2000, but it is no secret that forecasters everywhere did not anticipate the extent of disinflation in the U.S. economy in 2003 and, even after the fact, have had trouble explaining what happened. Moreover, the degree to which core inflation picked up in 2004 and 2005 also caught many economists, including this one on the FOMC, by surprise.

Surprises are inevitable; aggregate supply and demand curves shift for reasons that cannot be anticipated. But improvement should be possible in several dimensions. We could identify shocks sooner and get a better understanding of their likely effects on inflation. And we could attempt to narrow the definition of "shock." I suspect that much of what we consider to be exogenous is the working out of endogenous events that we do not understand very well.

Better predictions inevitably begin with improved understanding--both theoretical and empirical. In reviewing some of the advances of the past thirty-five years for this talk, I was struck by the degree to which so much of the work on rigidities and expectations seemed to be trying to find an elegant rationale at the level of the firm and the worker for the observed dynamic properties of aggregate price measures. This work, while illuminating in many respects, does not seem to have greatly advanced the empirical forecasting of inflation. And, the microeconomic behaviors we describe to justify the empirical specifications of our macroeconomic models often do not coincide very well with what we find when we directly observe the decisionmaking of workers and firms. I think we need to push forward along these microeconomic lines. I have a lengthy list of macroeconomic inflation puzzles whose answers would make me a better policymaker, but, for the most part, the solutions to the puzzles rest on a better understanding of how workers and firms set wages and prices.

Researchers at the ECB and at the euro-area national central banks have made an important contribution in their recent work. I agree with one of the conclusions I understand many of them came to--that is, we especially need to improve our understanding of the determinants of labor compensation. The reduced-form price

equations we so often use for inflation prediction bypass direct contact with labor compensation issues. But the labor market is at the foundation of the Friedman-Phelps analysis. Labor is the major element of business cost and as such often occupies a prominent role in policy discussions of inflation prospects, and the unemployment rate often proxies for resource slack more generally. As I have already discussed, unanticipated changes in the natural rate have contributed to forecasting errors over the past two decades. In the past few years, we have had some experience with wage setting under conditions of price stability, and nominal compensation showed greater flexibility than some observers had anticipated. Too often, discussions of wage and compensation determination rely on descriptions of worker demands and expectations that seem drawn from an era of strong unions rather than from the more atomistic labor markets that dominate the U.S. economy these days.

A better understanding of the motivation and dynamics of how compensation is determined between firms and individuals or small groups of workers would help unravel a number of the inflation puzzles I think we face, including those involving productivity growth, globalization, markups, and expectations formation.

#### *Changes in Productivity Growth*

An important aspect of this story has been that productivity affects prices before it affects wages--that is why we were able to experience low and stable inflation in the latter part of the 1990s with the unemployment rate well below any estimates of its natural level. But is it really true that prices are more responsive to productivity than wages? Why? Should the effects be symmetrical when productivity growth slows? How

can we better estimate structural productivity and determine changes in its pace of growth more promptly?

*Globalization and the Inflation Process*

Several observers have argued that increased trade has been an important factor in the downtrend in inflation over the past two decades.<sup>6</sup> One channel is said to be through greater competitive pressures and another through increased support for price stability engendered by the competitive environment. Globalization might restrain prices and wages in those sectors in which imports play an increasing role, but how does it hold back the average wage and price level? And, how do we reconcile the sense of greater competitive pressures with record levels of profits--and capital income more generally--in the United States?

*The Behavior of Profit Margins or Markups*

The Federal Reserve's 1970 conference and much of the work since then has approached the determination of inflation as a two-step process: model both labor costs and the price markup over labor costs. Yet, we find that this approach does not work very well in practice. Years of experience suggest that although profit margins tend to return to their mean, deviations can increase for a time and the eventual return can be slow and very difficult to predict. In the United States, markups have remained unusually elevated of late, absorbing little of the rise in the cost of energy, import, and materials. Does it matter whether the shock to margins comes from a change in potential

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<sup>6</sup> Kenneth S. Rogoff (2003), "Globalization and Global Disinflation," in *Monetary Policy and Uncertainty: Adapting to a Changing Economy*, proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City, August 28-30 (Kansas City: Federal Reserve Bank of Kansas City), pp. 77-112; Alan Greenspan (2005), "Globalization," speech presented to the Council on Foreign Relations, March 10.

supply or aggregate demand? What type of pricing behavior reconciles these outcomes?

How are they consistent with the expectation that margins return to means?

*Inflation Expectations*

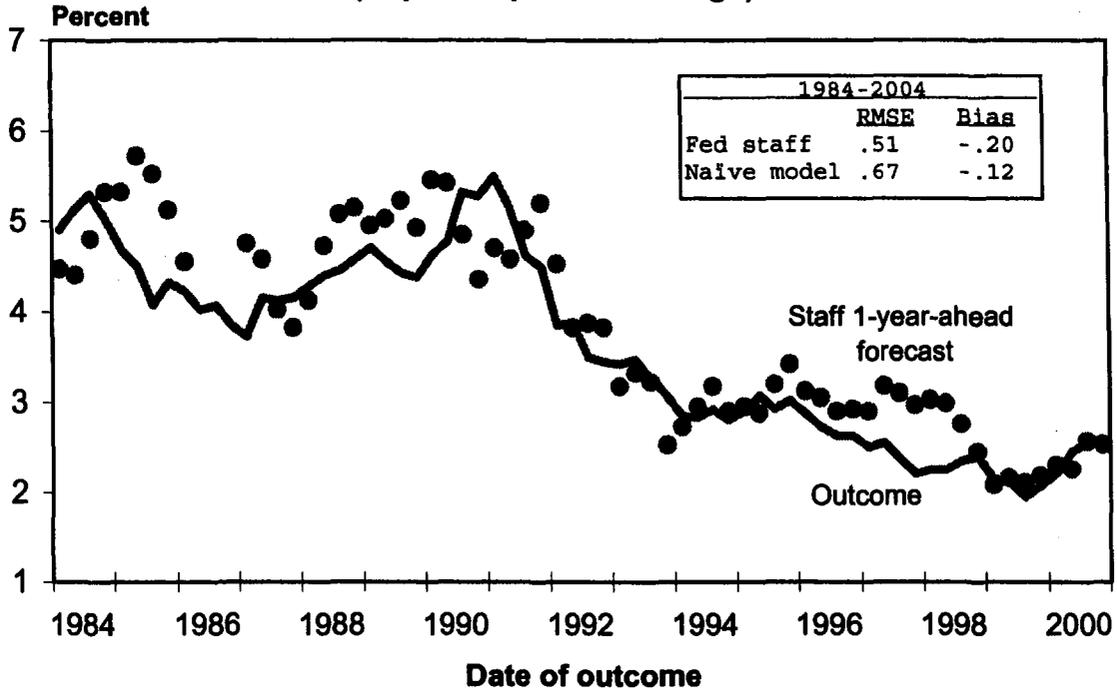
Measures of inflation expectations are among the variables I watch most closely as I formulate my policy recommendations because I recognize that changing expectations are a principal avenue by which short-term perturbations in price levels are propagated into more persistent changes in inflation rates. Yet our knowledge of the expectations that businesses and workers bring to the process of setting wages and prices is extremely limited. We use proxies--most often surveys of economists, whose projections may be influenced by their knowledge of other economists' projections, and of households, who may or may not understand the question or have a realistic view of what to expect. Readings from the financial markets are helpful, but they are also muddied by changing premiums for inflation risk and liquidity, and they are not necessarily representative of the attitudes of households or businesses.

Moreover, how expectations are formed remains an area that would benefit from further research. How much do people rely on the immediate past in forming expectations about the future? To what extent are projections from the past modified by what they know about the goals of the central bank or the stage and characteristics of the current economic cycle? How often do expectations get updated, and what types of information are used in the process?

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This is a daunting research agenda, but it should be given a high priority. I appreciate the opportunity to spell it out before an audience that has the skills and the opportunity to address some of these pressing questions.

## Staff Core CPI Forecast and Outcome, 1984-2000 (4-quarter percent change)



## Staff Core CPI Forecast Errors, 1984-2000 (1 year ahead)

