Inflation Dynamics: A Structural Econometric Analysis*

Jordi Galí
New York University and Universitat Pompeu Fabra

Mark Gertler
New York University

August 1998

Abstract

We develop and estimate a structural model of inflation that allows for a fraction of firms that use a backward looking rule to set prices. The model nests the purely forward looking New Keynesian Phillips curve as a particular case. We use measures of marginal cost as the relevant determinant of inflation, as the theory suggests, instead of an ad-hoc output gap. Real marginal costs are a significant and quantitatively important determinant of inflation. Backward looking price setting, while statistically significant, is not quantitatively important. Thus, we conclude that the New Keynesian Phillips curve provides a good first approximation to the dynamics of inflation.

*The authors thank participants at the NBER Summer Institute, and the JME-SNB Conference on "The Return of the Phillips Curve," for useful comments. Tomasso Monacelli and Fabio Natalucci provided excellent research assistance. Financial support from the C.V. Starr Center for Applied Economics is gratefully acknowledged.

1 Introduction

Among the central issues in macroeconomics is the nature of short run inflation dynamics. This matter is also one of the most fiercely debated, with few definitive answers available after decades of investigation. At stake, among other things, is the nature of business cycles and what should be the appropriate conduct of monetary policy.[1]

In response to this challenge, important advances have emerged recently in the theoretical modeling of inflation dynamics.[2] This new literature builds on early work by Fischer (1977), Taylor (1980), Calvo (1983) and others that emphasized staggered nominal wage and price setting by forward looking individuals and firms. It extends this work by casting the price setting decision within an explicit individual optimization problem. Aggregating over individual behavior then leads, typically, to a relation that links inflation in the short run to some measure of overall real activity, in the spirit of the traditional Phillips curve. The explicit use of microfoundations, of course, places additional structure on the relation and also leads to some important differences in details.

Despite the advances in theoretical modeling, accompanying econometric analysis of the "new Phillips curve" has been rather limited, though with a few notable exceptions[3]. The work to date has generated some useful findings, but these findings have also raised some troubling questions about the existing theory. As we discuss below, it appears difficult for these models to capture the persistence in inflation without appealing either to some form of stickiness in inflation that is hard to motivate explicitly or to adaptive expectations, which also poses difficulty from a modeling standpoint. In addition, with quarterly data, it is often difficult to detect a statistically significant effect of real activity on inflation using the structural formulation implied by theory, when the measure of real activity is an output gap (i.e., real output relative to some measure of potential output). Failure to find a significant short run link between real activity and inflation is obviously unsettling for the basic story.

In this context, we develop and estimate a structural model of the Phillips curve. Our approach has three distinctive features: First, we extend the baseline theory to allow for a subset of firms that set prices according to a backward looking rule of thumb. Doing so allows us to directly estimate the degree of departure from a pure forward looking model needed to account for the observed inflation persistence.

---

[1] For recent work that explores how the appropriate course of monetary policy depends on the nature of short run inflation dynamics, see Svensson (1997a, 1997b), Clarida, Gali and Gertler (1997b), Rotemberg and Woodford (1997b), McCallum and Nelson (1998), King and Wolman (1998), and Erceg, Henderson and Levin (1998).

[2] See Goodfriend and King (1997) for a comprehensive survey.

[3] Examples of work that attempts to estimate the new Phillips curve include, Chada, Masson and Meredith (1992), Fuhrer and Moore (1995), Fuhrer (1997), and Roberts (1997, 1998). For discussions of the traditional empirical literature on the Phillips curve, see King and Watson (1994), Gordon (1996) and Lown and Rich (1997).

Second, in the empirical implementation, we use measures of real marginal cost in place of an ad hoc output gap, as the theory suggests. As will become apparent, a desirable feature of a marginal cost measure is that it directly accounts for the impact of productivity gains on inflation, a factor that simple output gap measures often miss. In this respect, our approach is complementary to Sbordone (1998), though she does not directly estimate a model as we do.[4] Third, we identify and estimate all the structural parameters of the model using conventional econometric methods. The coefficients in our structural inflation equation are "mongrel" functions of two key model primitives: the average duration that an individual price is fixed (i.e., the degree of price "stickiness") and the fraction of firms that use rule of thumb behavior (i.e., the degree of "backwardness".)

As we show, several results stand out and appear to be quite robust: (a) Real marginal costs are indeed a statistically significant and quantitatively important determinant of inflation, as the theory predicts; (b) Forward looking behavior is very important: our model estimates suggest that roughly eighty percent of firms exhibit forward looking price setting behavior; (c) Backward looking behavior is statistically significant though of limited quantitative importance. Thus, while the benchmark pure forward looking model is rejected on statistical grounds, it appears still to be a reasonable first approximation of reality; (d) The average duration a price is fixed is considerable, but the estimates are in line with survey evidence.

Taken as whole, our results are supportive of the new theory based Phillips curves. But they also raise a puzzle. Traditional explanations of inertia in inflation (and hence the costs of disinflations) rely on some form of "backwardness" in price setting. To the extent this backwardness is not quantitatively important, as we seem to find, the story needs to be re-examined. In our view, the "black box" to investigate is the link between aggregate activity and real marginal costs. To the extent they are reasonably characterized by unit labor costs, real marginal costs tend to lag output over the cycle rather than move contemporaneously, in contrast to the prediction of the standard sticky price macroeconomic framework.[5] In this respect, our analysis suggests that a potential source of inflation inertia may be sluggish adjustment of real marginal costs to movements in output. We elaborate on this possibility in the conclusion.

The paper proceeds as follows: Section 2 reviews the basic theory underlying the new Phillips curve and discusses the existing empirical literature. Section 3 develops the structural econometric model of inflation. Section 4 presents estimates of the

[4] Because the pure forward looking model may be rejected when estimated conventionally, Sbordone (1998) instead explores how well it fits the data conditional on different choices of a parameter that governs the degree of price rigidity. Our approach is to specify a general model that nests the pure forward looking model directly, and then estimate the model directly using standard econometric methds. Despite the sharp differences in methodology, the main conclusions we draw are very similar to hers, as we discuss later.

[5] Christiano, Eichenbaum and Evans (1997) also stress that the standard sticky price framework does not seem to explain the cyclical behavior of marginal cost.

model's primitive parameters and a variety of robustness exercises. In addition, we construct a measure of "fundamental inflation" based on the solution to the estimated model that relates inflation to a discounted stream of expected future marginal costs, as well as lagged inflation. We in turn show that this measure does a good job of describing the actual path of inflation, including the recent period. Section 5 concludes.

2 The New Phillips Curve: Background Theory and Evidence

In this section we review the recent theory that generates an estimable Phillips curve relation. We then discuss some of the pitfalls involved in estimating this relation and how the literature has dealt with these issues to date. Finally, we describe our approach.

2.1 A Baseline Model

The typical starting point for the derivation of the new Phillips curve is an environment of monopolistically competitive firms that face some type of constraints on price adjustment. In the most common incarnations, the constraint is that the price adjustment rule is time dependent. For example, every period the fraction $\frac{1}{X}$ of firms set their prices for X periods. The scenario is in the spirit of Taylor's (1980) staggered contracts model. A key difference is that the pricing decision evolves explicitly from a monopolistic competitor's profit maximization problem, subject to the constraint of time dependent price adjustment.

In general, however, aggregation is cumbersome with deterministic time dependent pricing rules at the micro level: It is necessary to keep track of the price histories of firms. For this reason, it is common to employ an assumption due to Calvo (1983) that greatly simplifies the aggregation problem[6]. The idea is to assume that in any given period each firm has a fixed probability $1-\theta$ that it may adjust its price during that period and, hence, a probability θ that it must keep its price unchanged. This probability is independent of the time elapsed since the last price revision. Hence, the average time over which a price is fixed is given by $(1-\theta)\sum_{k=0}^{\infty} k\theta^{k-1} = \frac{1}{1-\theta}$. Thus, for example, with $\theta = .75$ in a quarterly model, prices are fixed on average for a year. Because the adjustment probabilities are independent of the firm's price history, the aggregation problem is greatly simplified.

[6] Examples of frameworks that employ the Calvo assumption include Yun (1996), King and Wolman (1995), Woodford (1996), Rotemberg and Woodford (1997a, 1997b), Clarida, Gali and Gertler (1997a), McCallum and Nelson (1998), and Bernanke, Gertler and Gilchrist (1998). For a general equilibrium sticky price model based on the Taylor (1980) formulation, see Chari, Kehoe and McGratten (1996) and Kiley (1997).

2.1.1 Inflation and Marginal Cost

The Calvo formulation leads to a Phillips curve with properties very close to the standard staggered price formulation, but at the same time it is more tractable[7]. From the standpoint of estimation, further, the parsimonious representation is highly advantageous. Let π_t denote the inflation rate at t (the percent change in the price level from $t-1$ to t); $\widehat{\psi}_t$ the percent deviation of the firm's real marginal cost from its steady state value; and β the subjective discount factor. By log-linearizing the first order condition for price setting (of a firm who is free to adjust price at t) and the price index it is possible to derive an inflation equation of the form:

$$\pi_t = \lambda\ \widehat{\psi}_t + \beta\ E_t \pi_{t+1} \qquad (1)$$

where the coefficient $\lambda \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$ depends on the frequency of price adjustment θ and the subjective discount factor β.[8]

Intuitively, because firms' are (a) monopolistic competitors that mark up price over marginal costs, (b) forward looking, and (c) must lock into a price for (possibly) multiple periods, they base their pricing decisions on the expected future behavior of marginal costs. Iterating equation (1) forward yields

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k\ \widehat{\psi}_{t+k} \qquad (2)$$

The benchmark theory thus implies that inflation should equal a discounted stream of expected future marginal costs.

2.1.2 Marginal Cost and the Output Gap

Traditional empirical work on the Phillips curve emphasizes some output gap measure as the relevant indicator of real economic activity, as opposed to marginal cost. Under certain assumptions, however, there is an approximate loglinear relationship between the two variables. Let y_t denote the log of output; y_t^* the log of the "natural" level of output (the level that would arise if prices were perfectly flexible); and $x_t (\equiv y_t - y_t^*)$ the "output gap". Then, under certain conditions one can write:[9]

---

[7] Roberts (1997) demonstrates that the Calvo (1983) and Taylor (1980) models have very similar implications for inflation dynamics. Indeed, the two period version of the Taylor model yields a solution for inflation that is quite close to that obtained from the Calvo formulation. Simulations by Jeanne (1998) indicate that the two approaches can generate very similar dynamics.

[8] For an explicit derivation, see, e.g., Goodfriend and King (1997), King and Wolman (1996), or Woodford (1996).

[9] In the standard sticky price framework without variable capital (e.g, Rotemberg and Woodford (1997)), there is an approximate proportionate relation between marginal cost and output. With variable capital the relation is no longer proportionate. Simulations suggest, however, that the relation remains very close to proportionate.

$$\begin{aligned} \widehat{\psi}_t &= \kappa\,(y_t - y_t^*) \\ &= \kappa\, x_t \end{aligned} \tag{3}$$

where κ is the output elasticity of marginal cost.

Combining equation equations (1) and (3) yields a Phillips curve-like relationship:

$$\pi_t = \lambda\kappa\; x_t + \beta\; E_t\pi_{t+1} \tag{4}$$

As with the traditional Phillips curve, inflation depends positively on the output gap and a "cost push" term that reflects the influence of expected inflation. A key difference is that it is $E_t\pi_{t+1}$ as opposed to $E_{t-1}\pi_t$ (generally assumed to equal π_{t-1}) that matters. As a consequence, inflation depends exclusively on the discounted sequence of future output gaps. This can be seen by iterating equation (4) forward, which yields:

$$\pi_t = \lambda\kappa \sum_{k=0}^{\infty} \beta^k\; E_t x_{t+k} \tag{5}$$

2.2 Empirical Issues

Reconciling the new Phillips curve with the data, has not proved to be a simple task. In particular, equation (4) implies that the current *change* in inflation should depend negatively on the lagged output gap. To see, lag equation (4) one period; and then assume $\beta \simeq 1$ to obtain

$$\pi_t = -\lambda\kappa\; x_{t-1} + \pi_{t-1} + \varepsilon_t \tag{6}$$

where $\varepsilon_t \equiv \pi_t - E_{t-1}\pi_t$. But estimating equation (6) with U.S. data (letting $x_t \simeq$ detrended log GDP) yields,

$$\pi_t = \underset{(0.040)}{0.081}\;\; x_{t-1} + \pi_{t-1} + \varepsilon_t \tag{7}$$

i.e., the inflation changes depends positively on lagged output rather than negatively: The estimated equation, unfortunately, resembles the old Phillips curve rather than the new !

The essential problem, as emphasized by Fuhrer and Moore (1995), is that the benchmark new Phillips curve implies that inflation should lead movements in the output gap: As equation (4) indicates, inflation equals a discounted sequence of future output gaps. In the data, however, movements in common proxies for the output gap (e.g., detrended output) tend to lead rather than lag inflation, as emphasized in the traditional Phillips curve literature [see, e.g., Fuhrer and Moore (1995)].

Another discomforting feature of the new Phillips curve as given by equation (4) is the stark prediction of no short run trade-off between output and inflation.

Put differently, equation (5) implies that a disinflation of any size could be achieved costlessly and immediately by a central bank that could commit to setting the path of future output gaps equal to zero. The historical experience suggests, in contrast, that disinflations involve a substantial output loss [e.g., Ball (1994)]. It may be possible to appeal to imperfect credibility to reconcile the theory with the data. If, for example, the central bank cannot commit to stabilizing future output, then reduction of inflation may involve current output losses [e.g., Ball (1995)]. While this theory clearly warrants further investigation, there is currently, however, little direct evidence to support it. Further, countries with highly credible central banks (e.g., Germany) have experienced very costly disinflations [e.g., Clarida and Gertler (1997)].

The empirical limitations of the new Phillips curve have led a number of researchers to consider a hybrid version of the new and old:

$$\pi_t = \delta\, x_t + (1-\phi)\; E_t\pi_{t+1} + \phi\; \pi_{t-1} \tag{8}$$

with $0 < \phi < 1$. The idea is to let inflation depend on a convex combination of expected future inflation and lagged inflation. The addition of the lag term is designed to capture the inflation persistence that is unexplained in the baseline model.[10] A further implication of the lag term is that disinflations now involve costly output reduction.

The motivation for the hybrid approach is largely empirical. Fuhrer and Moore (1995) appeal to Buiter and Jewitt's (1985) relative wage hypothesis. While the story may be plausible, it does not evolve from an explicit optimization problem, in contrast to the benchmark formulation. Roberts (1997, 1998) instead appeals to adaptive expectations on the part of a subset of price setters. Under his formulation, some form of adaptive rule replaces lagged inflation.

Oddly enough, however, the hybrid Phillips curve has met with rather limited success. In particular, the relation does not seem to provide a good characterization of inflation dynamics at the quarterly frequency. Chadha, Masson, and Meredith (1992), for example, obtain reasonable parameter estimates of equation (8), but only with annual data. Roberts (1997, 1998) similarly works mainly with annual and semi-annual data. With quarterly data, he has difficulty obtaining significant estimates of the effect of the output gap on inflation. Fuhrer (1997) is able to obtain a significant output gap coefficient with quarterly data, but only when the model is heavily restricted. In this instance the estimated model is consistent with the old Phillips

[10] A special case of equation (8) with $\phi\ = 0.5$ is the widely used "sticky inflation" model of Buiter and Jewitt (1985) and Fuhrer and Moore (1995):

$$(\pi_t - \pi_{t-1}) = \frac{\delta}{0.5}\; x_t + \;(E_t\pi_{t+1} - \pi_t) \tag{9}$$

Under this formulation, the *change* in the inflation rate is related the expected path of the future output gaps.

curve: expected future inflation does not enter significantly in the inflation equation; lagged inflation enters with a coefficient near unity, as in the traditional framework.

There are however, several problems with this approach that could possibly account for the empirical shortcomings. First, conventional measures of the output gap x_t are likely to be ridden with error, primarily due to the unobservability of the natural rate of output y_t^*.[11] A typical approach to measuring y_t^* is to use a fitted deterministic trend. Alternatives are to use the Congressional Budget Office (CBO) estimate or instead use a measure of capacity utilization as the gap variable. It is widely agreed that all these approaches involve considerable measurement error. To the extent there is significant high frequency variation in y_t^* (e.g., due to supply shocks) mismeasurement could distort the estimation of an inflation equation like (4) or (8).[12]

A more fundamental issue in our view, however, is that even if the output gap were observable the conditions under which it corresponds to marginal cost may not be satisfied. Our analysis of the data suggests that movements in our measure of real marginal cost (described below) tend to lag movements in output, in direct contrast to the identifying assumptions that imply a co-incident movement. This discrepancy, we will argue, is one important reason why structural estimation of Phillips curves based on the output gap may be problematic.

2.3 Our Approach

In light of the difficulties with using the output gap, we instead use in the empirical analysis below measures of real marginal cost, in a way consistent with the theory. Since real marginal cost is not directly observable, we use restrictions from theory to derive a measure based on observables. In constructing the measure, we consider several alternative hypotheses about technology.

In addition, we derive an econometric specification for inflation that resembles the "hybrid Phillips curve" by extending the Calvo framework to allow for a subset of firms that use backward looking rules of thumb to set prices. The advantage of proceeding this way is that the coefficients of our hybrid Phillips curve (including the coefficient on real marginal costs) are functions of two key primitives that we can identify and estimate using conventional econometric methods: the frequency of price adjustment and the fraction of backward looking-price setters. The former parameter measures the degree of price stickiness, while the latter measures the departure from

[11] This issue is currently of great practical importance in the U.S.: in recent years the measured output gap is well above trend, but inflation is well below trend. It thus appears that mismeasurement of the true output gap is confounding the ability of traditional Phillips curves to explain the data. See Lown and Rich (1997).

[12] For example, in the presence of nominal rigidities, supply shocks are likely to move detrended output and the true output gap in opposite directions [Gali (1998)]. In addition, unobserved supply shocks could potentially account for some of the explanatory power of lagged inflation.

a pure forward looking model needed to account for the persistence in inflation[13].

3 A Structural Model of Inflation Dynamics

In this section we develop a structural model of inflation dynamics that is both tractable and suitable for estimation. Our starting point is a version of Calvo's (1983) model of staggered price setting.

There is a continuum of firms of measure one. Each is a monopolistic competitor that produces a differentiated product. Let $P_t(z)$ and $Y_t(z)$ denote nominal price and output for firm z, and P_t and Y_t be the corresponding aggregate values. Firm z faces the following conventional constant elasticity demand function for its output

$$Y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon} Y_t$$

As in Calvo's model, each firm is able to adjust its price in any given period with a fixed probability $1-\theta$, which to facilitate aggregation, is independent of the time the price has been fixed. We depart from Calvo by having two types of firms coexist. A fraction $1-\omega$ of the firms, which we refer to as "forward looking," behave like the firms in Calvo's model: they set prices optimally, given the constraints on the timing of adjustments and using all the available information in order to forecast future marginal costs. The remaining firms, of measure ω, and which we refer to as "backward looking," instead use a simple rule of thumb that we describe below, and which requires only some past information on aggregate price behavior.[14]

We next proceed to describe formally the price setting behavior by both types of firms. We then aggregate to derive a structural inflation equation.

3.1 Forward Looking Firms

As in the standard Calvo setup, these firms choose the nominal price, denoted by P_t^f, in order to maximize expected discounted profits, given the anticipated demand for their good, their technology, and the constraints on future price readjustments. Let ψ_t^n be the firm's nominal marginal cost in period t. Then, as in Calvo's model, the optimal price P_t^f is a markup over a weighted average of expected future nominal

[13] In this vein, the approach is similar to the way Campbell and Mankiw (1989) tested the life cycle/permament income hypothesis of consumption. Rather than simply reject a pure forward looking model, they allowed for some rule of thumb consumers to provide a metric of how far the baseline model is from the data.

[14] Ghezzi (1997) develops a continuous time variant of the Calvo model that allows for backward-looking price setters. In addition to being in discrete time, our formulation differs in that we require that the backward looking rule be consistent with forward looking behavior in the steady state, so that there are no persistent departures between optimal and rule of thumb behavior.

marginal costs, as follows:

$$P_t^f = \mu \sum_{k=0}^{\infty} E_t \left\{ \omega_{t,t+k} \; \psi_{t+k}^n \right\} \tag{10}$$

where $\mu \equiv \frac{\epsilon}{\epsilon-1}$ (which corresponds to the desired markup under flexible prices), and with the weight $\omega_{t,t+k}$ being

$$\omega_{t,t+k} \equiv \frac{\theta^k \; Q_{t,t+k} \; D_{t+k}(P_t^f)}{\sum_{h=0}^{\infty} \theta^h \; E_t[Q_{t,t+h} \; D_{t+h}(P_t^f)]}$$

where $D_{t+k}(P_t^f) \equiv \left(\frac{P_t^f}{P_{t+k}}\right)^{1-\epsilon} Y_{t+k}$ is the firm's revenues at $t+k$ conditional on P_t^f, and $Q_{t,t+k}$ is the relevant stochastic discount factor between t and $t+k$. Note that as θ converges to 0 – the case where all firms reset their prices every period – then equation (10) converges to the conventional static optimal pricing condition, i.e., $P_t^f = \mu \; \psi_t^n$.

3.2 Backward Looking Firms

Backward looking firms are assumed to follow a rule of thumb that has the following two features: (a) no persistent deviations between the rule and optimal behavior; i.e., in a steady state equilibrium the rule is consistent with optimal behavior; (b) the price in period t given by the rule depends only on information dated at $t-1$ or earlier. These considerations lead us to a simple rule that is based on the most recent round of price adjustments by the firm's competitors: Let $P_t^b(z)$ be price charged by a backward looking firm z that is adjusting its price at t. Then, P_t^b is assumed to obey

$$\frac{P_t^b(z)}{P_{t-1}^b(z)} = \left(\frac{P_{t-1}^*}{P_{t-2}}\right)\left(\frac{P_{t-1}}{P_{t-1}^b(z)}\right) \tag{11}$$

where P_{t-1}^* is an index of new prices posted at $t-1$.

According to equation (11), the gross price adjustment at t under the rule, $\frac{P_t^b(z)}{P_{t-1}^b(z)}$, equals the average gross price adjustment by those who changed price in the previous period, $\frac{P_{t-1}^*}{P_{t-2}}$, times a factor $\frac{P_{t-1}}{P_{t-1}^b(z)}$ which corrects for the firm's relative price in that period. Intuitively, $\frac{P_{t-1}^*}{P_{t-2}}$ provides a guide as how much the firm should change price at t since it reflects the average adjustment by firms that had to make a similar decision just one period earlier. This measure is adjusted by the firm's relative price at t to correct for the initial position of the firm's price relative to the average (e.g., a firm that has its price above average in $t-1$ will increase it by less at t, everything else equal). Note that equation (11) simplifies to

$$P_t^b(z) = \left(\frac{P_{t-1}^*}{P_{t-2}}\right) P_{t-1} \tag{12}$$

Thus, all rule of thumb adjusters choose the same price P_t^b at t.

Several observations are in order. First, even though the rule is based on past price adjustments (by other firms), it does implicitly incorporate information about the future, since the price index P_{t-1}^* is partly determined by forward looking price setters. Second, the rule corresponds to optimal behavior in the steady state, since both backward and forward looking price setters will adjust at the same rate in this circumstance. Third, to the extent the percent difference between the forward and backward price is not large, the loss to a firm from rule of thumb behavior will be second order, for the usual arguments due to the envelope theorem. This is more likely to be the case if backward looking price setters are a relatively small fraction of the population.[15]

3.3 A Structural Phillips Curve

The aggregate price index P_t may be expressed as:[16]

$$P_t = \left[\theta\ (P_{t-1})^{1-\epsilon} + (1-\theta)\ (P_t^*)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{13}$$

with

$$P_t^* = \left[\omega\ (P_t^b)^{1-\epsilon} + (1-\omega)\ (P_t^f)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{14}$$

It is convenient to express the prices set by forward and backward looking firms, equations (10) and (12) relative to the overall price index P_t, as follows:

$$q_t^f \equiv \frac{P_t^f}{P_t} = \mu \sum_{k=0}^{\infty} E_t \left\{\omega_{t,t+k}\ \pi_{t,t+k}\ \psi_{t+k}\right\} \tag{15}$$

$$q_t^b \equiv \frac{P_t^b}{P_t} = q_{t-1} \left(\frac{1+\pi_{t-1}}{1+\pi_t}\right) \tag{16}$$

where $\pi_{t,t+k} \equiv \frac{P_{t+k}}{P_t}$, $\psi_t \equiv \frac{\psi_t^n}{P_t}$, and $q_t \equiv \frac{P_t^*}{P_t}$. Using the newly defined variables, and combining equations (13) and (14) we can obtain an expression determining the current rate of inflation $\pi_t \equiv \frac{P_t}{P_{t-1}} - 1$ as a function of the relative prices set by the two types of firms in period t :

$$\theta\ (1+\pi_t)^{\epsilon-1} = 1 - (1-\theta)\ \left[\omega\ (q_t^b)^{1-\epsilon} + (1-\omega)\ (q_t^f)^{1-\epsilon}\right] \tag{17}$$

[15] When backward looking price-setters are a relatively small fraction of the population, the index of newly set prices P_t^* is dominated by forward looking price setters. Given that P_t^b closely tracks P_{t-1}^*, the backward looking price will be close on average to the forward looking price. We have conducted simulations of a complete model that bear out this logic.

[16] Given the firm's demand function, the price index is the following CES aggregator over the prices of individual goods: $P_t = [\int_0^1 (P_t(z)_t)^{1-\epsilon} dz]^{\frac{1}{1-\epsilon}}$

To obtain our structural Phillips curve, we log-linearize equations (15), (16), and (17) around a zero inflation steady state (where $q^b = q^f = q = 1$, and $\psi = \mu^{-1}$), and then combine them to obtain:[17]

$$\pi_t = \lambda\, \widehat{\psi}_t + \gamma_f\ E_t \pi_{t+1} + \gamma_b\ \pi_{t-1} \tag{18}$$

where

$$\lambda = \frac{(1-\omega)\ (1-\theta)\ (1-\beta\theta)}{\theta + \omega\ \ (1-\theta(1-\beta))} \tag{19}$$

$$\gamma_f = \frac{\beta\theta}{\theta + \omega\ \ (1-\theta(1-\beta))} \tag{20}$$

$$\gamma_b = \frac{\omega}{\theta + \omega\ \ (1-\theta(1-\beta))} \tag{21}$$

This specification differs from the hybrid model used in recent empirical research (discussed in the previous section) in two fundamental ways. First, real marginal cost as opposed to the output gap is the forcing variable. Second, all the coefficients are explicit functions of three model parameters: θ, which measures the degree of price stickiness; ω, the degree of "backwardness" in price setting, and the discount factor β.

Two special cases provide useful benchmarks: First, when $\omega = 0$, all firms are forward looking and the model converges to the benchmark new Phillips curve introduced in the previous section. Second, when $\beta = 1$, then $\gamma_f\ + \gamma_b = 1$, which implies that the model takes the form of hybrid equation discussed earlier (except that marginal cost and not the output gap appears now as the driving force).

3.4 Econometric Specification

To estimate equation (18), we first need to obtain a measure of real marginal cost. We assume a Cobb-Douglas technology which allows for overhead labor. Let Z_t denote technology, K_t capital, N_t total labor and $\overline{N}$ overhead labor. Then output Y_t is given by

$$Y_t = Z_t\ K_t^{\alpha}\ (N_t - \overline{N})^{1-\alpha} \tag{22}$$

[17] The log-linearized equations are:

$$\widehat{q}_t^f = \beta\theta\ E_t \widehat{q}_{t+1}^f + \beta\theta\ E_t \pi_{t+1} + (1-\beta\theta)\ \widehat{\psi}_t$$

$$\widehat{q}_t^b = \widehat{q}_{t-1} + \pi_{t-1} - \pi_t$$

$$\theta\ \pi_t = (1-\theta)\ \left[\omega\ \widehat{q}_t^b + (1-\omega)\ \widehat{\varphi}_t^f\right]$$

which can be combined to obtain (18).

We include overhead labor as a simple way to account for the presence of either increasing returns or labor hoarding in measuring real marginal cost.[18] We note also that the approach is robust to adding additional inputs, such as raw materials, so long as these inputs enter in the production function in Cobb-Douglas form.[19]

Real marginal cost is given by the ratio of the wage rate to the marginal product of labor, i.e., $\psi_t = \frac{W_t}{P_t} \frac{1}{\partial Y_t / \partial N_t}$. Hence, given equation (22) we have:

$$\begin{aligned} \psi_t &= \frac{W_t/P_t}{(1-\alpha)Y_t} \left(N_t - \overline{N}\right) \\ &= \frac{s_t^N}{1-\alpha} \left(1 - \frac{\overline{N}}{N_t}\right) \end{aligned} \tag{23}$$

where $s_t^N \equiv \frac{W_t N_t}{P_t Y_t}$ is the labor income share (equivalently, real unit labor costs)[20].

3.4.1 Constant Returns

In the baseline case of constant returns, $\overline{N} = 0$, which implies $\psi_t = \frac{s_t^N}{1-\alpha}$. Log-linearizing around the steady state implies that the percent deviation in marginal costs correspond to the percent deviations in the labor share:

$$\widehat{\psi}_t = \widehat{s}_t^N \tag{24}$$

Combining equations (24) and (18) yields the following econometric specification for inflation:

$$\pi_t = \lambda \, \widehat{s}_t^N + \gamma_f \, \pi_{t+1} + \gamma_b \, \pi_{t-1} + \varepsilon_{t+1} \tag{25}$$

where $\varepsilon_{t+1} = E_t \pi_{t+1} - \pi_t$, which, under rational expectations, is uncorrelated with information available at t. It follows that, in principle, variables dated t and earlier are valid instruments for estimation of equation (25). In addition, the coefficients λ, γ_f, and γ_b must satisfy the restrictions given by equations (19), (20), and (21).

[18] The measure of adjustment costs may also be sensitive to adjustment costs of labor. Allowing for internal adjustment costs of labor is problematic since the addition of another state variable (lagged employment) to the firm's decision problem may complicate the aggregation of optimal price setting behavior. Assuming external adjustment costs, though perhaps less realistic, facilitates aggregation and may be satisfactory from the standpoint of capturing the impact of adjustment costs on marginal costs. In any event, we plan to explore this avenue.

[19] Let X_t denote inputs other than labor and capital (e.g., raw materials). Suppose now that $Y_t = Z_t \; (K_t^\alpha \; (N_t - \overline{N})^{1-\alpha})^\eta X_t^{1-\eta}$, with $0 < \eta < 1$. Then it is straightforward to verify that our expressions for marginal cost remain unchanged. If raw materials instead enter in Leontief form, then it is necessary to distinguish bewteen value-added and gross production. See, e.g., Benabou (1992).

[20] Interestingly, Lown and Rich (1997) show that augmenting the growth of a traditional Phillips curve with the growth rate of nominal unit labor costs greatly improves the fit. We also stress the role of unit labor costs, except that in our approach, (the log level) of real unit labor costs enters as the relevant gap variable, as the theory suggests.

3.4.2 Increasing Returns

In this instance, $\overline{N} > 0$. We pin $\overline{N}$ down by the requirement of zero profits in the steady state, which implies $\psi = 1 - \frac{\overline{N}}{N}$. Log-linearizing equation (23) around the zero profit steady state then yields:

$$\widehat{\psi}_t = \widehat{s}_t^N + (\mu - 1)\ \widehat{N}_t \tag{26}$$

where $\mu \equiv \psi^{-1}$ is the steady state markup (as well as an index of increasing returns). Combining equations (26) and (18) then yields

$$\pi_t = \lambda\ \widehat{s}_t^N + \lambda(\mu - 1)\ \widehat{N}_t + \gamma_f\ \pi_{t+1} + \gamma_b\ \pi_{t-1} + \varepsilon_{t+1} \tag{27}$$

where, again, λ, γ_f, and γ_b must satisfy the restrictions given by equations (19), (20), and (21).

Equations (25) and (27) form the basis of the empirical analysis described next.

4 Estimation and Results

In this section we present estimates of our structural model and also evaluate its overall performance vis-a-vis the data. We begin with the baseline case of constant returns described in the previous section. We then consider a variety of robustness exercises that include: alternative specifications, alternative measures of marginal costs, and sub-sample stability. Finally, to assess how well the equation describes the data, we construct a measure we term "fundamental inflation" that is implied by our model, and show it does a good job of characterizing the actual behavior of inflation, including its behavior in recent years (which represents a real puzzle for "conventional" inflation equations).

4.1 Estimates of the Baseline Model

We estimate the structural parameters β, θ, and ω using a non-linear instrumental variables estimator applied to (25) given (19)-(21). We use quarterly U.S. data for the period 1960:1 to 1996:4. We use the percent change in the GDP deflator for π_t; and the labor income share in the non-farm business sector for s_t^N. We use as instruments four lags of inflation, the labor income share, employment, the long-short interest rate spread, wage inflation, and commodity price inflation.[21]

Table 1 presents the estimates for the baseline model, with standard errors in parentheses. Three cases are considered. The first imposes the restrictions on the coefficients of (25) given by equations (19)-(21). The second adds the restriction $\beta = 1$, implying $\gamma_b + \gamma_f = 1$. The third presents an unrestricted direct estimate of

[21] We include only lagged values as instruments to allow for the possibility of an i.i.d. error term in backward looking price setting.

the coefficients λ, γ_f, and γ_b in equation (25). In the first two cases, we also report the estimates of λ, γ_f, and γ_b implied by the estimates of θ, β, and ω.

In each case the parameters are precisely estimated and consistent with the underlying theory. The results, further, are reasonably consistent across specifications. In each case the specification is not rejected, as indicated by the p values corresponding to a test of the model's overidentifying restrictions, reported in the last column of Table 1.

We begin with the basic case. The parameter θ is estimated to be 0.8 with standard error 0.02, which implies that prices are fixed for roughly five quarters on average[22]. That period length may seem a bit long, but is not far off from survey evidence which suggests three to four quarters.[23] The parameter ω is estimated to be 0.23 with a standard error 0.05, implying that between a fifth and quarter of price setters are backward looking. Thus, the pure forward looking model is rejected by the data. However, the quantitative importance for inflation dynamics of backward looking behavior is relatively small. The estimates thus suggest that the benchmark forward looking model may not be an unreasonable approximation of reality.

The estimates of the primitive parameters yield an estimate of the slope coefficient on the labor share λ that is positive and significant[24]. Thus, we are able to identify a significant impact of marginal costs on inflation. The weight on future inflation γ_f is estimated to be roughly four times the weight on lagged inflation γ_b. The difference, of course, reflects relative unimportance of backward looking price setters. The sum $\gamma_f + \gamma_b$ is less than unity, however, in contrast to conventional hybrid model described in the previous section. This outcome arise because the discounted β is estimated to be below unity at 0.85. Thus, the estimates suggests that price setters discount the future more heavily than what is implied in the conventional hybrid case.

We next explore the implications of restricting β equal to unity, as implied in the standard hybrid case. Interestingly, there is little impact on the estimates of the other primitive parameters. The parameter θ is virtually unchanged. The weight ω declines slightly to 0.19, but does not appear significantly different from the previous case. Thus, though the slope coefficients γ_f and γ_b are now restricted to sum to unity, the relative magnitudes remain roughly the same. The coefficient on marginal cost,

[22] Interestingly, Sbordone (1998) finds that the value of the price adjustment parameter that maximizes the goodness of fit of the data by Watson's (1993) criteris also corresponds to an average of five quarters between adjustments. Thus, despite the difference in methodology, our results line up very closely with hers.

[23] For a discussion of the survey evidence, see Rotemberg and Woodford (1997a). Our sub-sample estimates (reported shortly) yield numbers directly in line with this evidence.

[24] We note that the link between inflation and marginal cost is related to Benabou's (1992) finding that, based on retail trade data, inflation is inversely related to the markup (which he measured as the inverse of the labor share.) He interpreted the findings as evidence that the markup may depend on inflation, whereas in our model, causation runs from marginal cost to inflation. Sorting out possible simultaneity is an interesting topic for future research. We note, however, that our model has the additional implication that inflation should be related to a discounted stream of future marginal costs, and we shortly demonstrate that this appears to be the case.

further, remains significantly positive and is not much different from the previous case.

The coefficient λ remains significantly positive in the unrestricted case. Though the point estimate is smaller, it is not significantly different from the other cases. Forward looking behavior still predominates, but the relative importance of backward looking price setters appears to rise. The estimated ratio of γ_b to γ_f suggests that roughly forty-five percent of price setters may be backward looking. These results of course do not employ the restrictions from the underlying theory. However, it is an open question as to whether alternative specifications of backward looking behavior might lead to higher estimates of ω. At the same time, we stress that even the unrestricted estimates suggest that forward looking behavior is very important to inflation dynamics.

4.2 Robustness Analysis

We now consider the effects of some alternative formulations and also explore sub-sample stability. Table 2 presents results for three alternative cases to the baseline model. The first allows for increasing returns, as described in the previous section. The second allows extra lags of inflation to enter the right hand side. The final uses a comprehensive measure of the labor share to measure marginal cost.

To allow for increasing returns in the measure of marginal cost, we estimate equation (27) subject to (19)-(21). As Table 2 indicates, the results remain largely unchanged from the previous case. The coefficient estimates are very similar. Further, there is no evidence of increasing returns to scale. Regardless of whether β is restricted to unity, the estimate of $\mu - 1$ is not significantly different from zero. Thus, we cannot reject the baseline assumption of constant returns to scale.

We next add three additional lags of inflation to the baseline case (equation (25)). Here the idea is to explore whether our estimated importance of forward looking behavior may reflect not allowing for sufficient lagged dependence. The parameter ϕ is the sum of the coefficients on the additional inflation lags. The overall effect of the additional lags is quite small and is only significant when β is restricted to unity. Thus, even though a total of three lags of inflation enters the right hand side, forward looking behavior still predominates.

Finally, Table 2 reports the effects of using a comprehensive measure of the labor income share in contrast to the non-farm business measure. The difference is the former includes government and the farm sector. Again, the results are largely unchanged.

We next consider sub-sample stability. Table 3 reports estimates over the intervals *60:1-79:4*, *70:1-89:4*, and *80:1-96:4*. The broad picture remains unchanged. Marginal costs have a significant impact on short run inflation dynamics of roughly the same quantitative magnitudes as suggested by the full sample estimates. Forward looking behavior is always important. In the first two sub-periods, the estimate of

ω is close to the full sample estimate; i.e. roughly 0.23. Interestingly, though, in the last sub-period the estimate of ω drops to zero. Thus, we cannot reject the pure forward looking model over the 1980:1 to 1996:4 period.

Another interesting result is that the estimate of θ for the first two sub-samples drops from the full sample estimate of 0.8 to the range $0.71 - 0.75$. The important implication is that pre-1990, the estimated average duration a price is fixed is between three and four quarters, which is directly in line with the survey evidence. For the last sample, 1980:1 -1996:4, the estimate of θ rises to roughly $0.81-0.83$, implying duration of five to six quarters. The longer duration might reflect the fact that inflation was lower over the last sub-sample. As a consequence, the average length between price adjustments may have increased (as, for example, a model of state-dependent pricing might imply.)

4.3 Actual vs. Fundamental Inflation

Our econometric Phillips curve, as given by equation (25), takes the form of a difference equation for inflation, with expected real marginal costs as the forcing variable. The solution for inflation implied by the model will depend on a discounted stream of expected future marginal costs and also lagged inflation. A way to assess the model's goodness-of-fit, we consider how well the solution to the difference equation lines up against the actual data. We term our model-based measure of inflation "fundamental" inflation because it is analogous to Campbell and Shiller's (1987) construct of fundamental stock prices in terms of forecasts of discounted future dividends.

Our baseline estimates of γ_b and γ_f imply the existence of one stable and one unstable root associated with the stationary solution to the difference equation for inflation given by (25). Let $\delta_1 \leq 1$ denote the stable root and $\delta_2 \geq 1$ denote the unstable root. The model's solution is then given by:

$$\pi_t = \delta_1 \pi_{t-1} + \left(\frac{\lambda}{\delta_2 \gamma_f}\right) \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k E_t \ \widehat{s}_{t+k}^N \qquad (28)$$

The lagged term in equation (28) arises from the presence of backward looking price setters. In the benchmark case with pure forward looking behavior, the lagged term disappears (i.e.e, $\delta_1 = 0$).

Let $I_t = \{\pi_t, \pi_{t-1,...,} \ z_t, \ z_{t-1}, ...\}$ where z_t is a vector of variable other than inflation. Taking expectations conditional on I_t on both sides of (28):

$$\pi_t = \delta_1 \pi_{t-1} + \left(\frac{\lambda}{\delta_2 \gamma_f}\right) \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k E[\ \widehat{s}_{t+k}^N \mid I_t] \equiv \pi_t^* \qquad (29)$$

We construct our measure of fundamental inflation π_t^* using equation (29) based on $I_t = \{\pi_t, \ \pi_{t-1,...,} \ \widehat{s}_t^N, \ \widehat{s}_{t-1}^N, ...\}$. Figure 1 plots π_t^* versus actual inflation π_t.

Overall fundamental inflation tracts the behavior of actual inflation very well.[25] It is particularly interesting to observe that it does a good job of explaining the recent behavior of inflation. During the past several years, of course, inflation has been below trend. Output growth has been above trend, on the other hand, making standard measures of the output gap highly positive. As a consequence, traditional Phillips curve equations have been overpredicting recent inflation.[26] However, because, real unit labor costs have been quite moderate recently despite rapid output growth, our model of fundamental inflation is close to target.

5 Conclusions

Our results suggest that, conditional on the path of real marginal costs, the baseline new Phillips curve with forward looking behavior may provide a reasonably good description of inflation dynamics. The structural estimates suggest that backward looking price setting, while statistically significant, is not quantitatively important. One, qualification, however, is that when we do not exploit all the implications of our theory in the estimation, the importance of backward looking behavior rises, though forward looking behavior remains predominant. Taken as a whole, however, the results suggest that it is worth searching for explanations of inflation inertia beyond the traditional ones.

One important avenue to investigate, we think, involves the cyclical behavior of real marginal cost. Figure 2 presents sets of cross-correlations that help frame the issue. The data is quarterly from 1965:1-1996:4 and is detrended with a quadratic trend. The top panel is the cross-correlation of inflation (the percent change in the GDP deflator) with the output gap (the percent difference in real GDP with the CBO estimate of potential GDP.) The middle row is inflation with real marginal costs (as measured by the log of real unit labor costs). The last row is real marginal costs with the output gap.

Among other things, the figure makes clear why real unit labor costs outperforms the output gap in the estimation of the new Phillips curve. As the top panel indicates, the output gap leads inflation, rather than vice-versa, in direct contradiction of the theory (see equation (5)). In contrast, as the middle panel indicates, real unit labor costs exhibit a strong contemporaneous correlation with inflation. Further, inflation lagged both two and four quarters is positively correlated with current unit labor costs, consistent with the theory. Thus, (with the benefit of this hindsight), it is perhaps not surprising why real unit labor costs enters the structural inflation equation

[25] Sbordone (1998) similarly finds that inflation is well explained by a discounted stream of future real marginal costs, though using a quite different methodology to parametrize the model.

[26] An exception is Lown and Rich (1997). Because they augment a traditional Phillips curve with the growth in nominal unit labor costs, their equation fares much better than the standard formulation. Though the way unit labor costs enters our formulation is quite different, it is similarly the sluggish behavior of unit labor costs that helps the model explain recent inflation.

significantly and with the right sign. The last row completes the picture: Real unit labor costs lag the output gap in much the same way as does inflation. The lag in the response of real unit labor costs explains why the output gap performs poorly in estimates of the new Phillips curve.

It is also true that the sluggish behavior of real marginal cost might help account for the slow response of inflation to output and thus (possibly) why disinflations may entail costly output reductions.[27] For this reason, modifying existing theories to account for the rigidities in marginal costs suggested by Figure 2 could offer important insights for inflation dynamics.[28] Given the link between unit labor costs and marginal costs, a candidate source for the necessary friction is wage rigidity. Indeed, a likely reason for the strong counterfactual contemporaneous positive correlation between output and real marginal cost in the standard sticky price framework is the absence of any type of labor market frictions [see, e.g., the discussion in Christiano, Eichenbaum and Evans (1997)]. At this stage, one cannot rule out whether it is nominal or real wage rigidities that can provide the answer. Both seem worth exploring.

[27]Interestingly, Blanchard and Muet (1992) find that disinflations in France have been associated with declines in real unit labor costs. In this respect it seems worth exploring data from other countries.

[28]The existing literature on business cycle models that features sticky prices has long emphasized the need to incorporate real rigidities (see, e.g., Blanchard and Fischer (1989) and Ball and Romer (1990)). Typically, however, the discussion is in terms of trying to explain a large response of output to monetary policy: Real rigidities help flatten the short run marginal cost curve. However, it is also the case, as we have been arguing, that real rigidities may be needed to account for inflation dynamics, and in particular the sluggish response of inflation to movements in output.

REFERENCES

Ball, Laurence (1994): "What Determines the Sacrifice Ratio ?," in G. Mankiw, ed., *Monetary Policy,* Chicago University Press.

Ball, Laurence (1995), "Disinflation with Imperfect Credibility," *Journal of Monetary Economics* 35, 5-24.

Ball, Laurence and David Romer (1990), "Real Rigidities and the Non-Neutrality of Money," *Review of Economic Studies,* 183-204.

Blanchard, Olivier and Pierre Alain Muet (1992), "Competitiveness Through Disinflation: An Assessment of the French Macro-Strategy," mimeo, M.I.T.

Blanchard, Olivier and Stanley Fischer (1989), *Lectures on Macroeconomics,* M.I.T. Press.

Benabou, Roland, (1992), "Inflation and Markups: Theories and Evidence from the Retail Trade Sector, *European Economic Review,* 36, 566-574.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist, (1998), "The Financial Accelerator in a Quantitative Business Cycle Framework," in the *Handbook of Macroeconomics*, John Taylor and Michael Woodford eds.

Buiter Willem and Ian Jewitt, "Staggered Wage Setting with Real Wage Relativities: Variations on a Theme of Taylor," in *Macroeconomic Theory and Stabilization Policy (*University of Michigan Press, Ann Arbor), 183-199.

Calvo, Guillermo A. (1983): "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, 383-398.

Campbell, John Y. and N. Gregory Mankiw (1989), "Consumption, Income and Interest Rates: Re-interpreting the Times Series Evidence," *NBER Macroeconomics Annual,* edited by Olivier Blanchard and Stanley Fischer (M.I.T. Press).

Campbell, John Y. and Robert Shiller (1987), "Cointegration and Tests of the Present Value Relation," *Journal of Political Economy* 95, 1062-1088.

Chadha, Bankim, Paul R. Masson and Guy Meredith (1992), "Models of Inflation and the Costs of Disinflation," *IMF Staff Papers,* vol.39, no. 2, 395-431.

Chari, V.V., Patrick Kehoe and Ellen McGratten, (1996), "Sticky Price Models of the Business Cycle: The Persistence Problem," manuscript, University of Minnesota.

Christiano, Lawrence J., Martin Eichenbaum and Charles Evans (1997), "Sticky Price and Limited Participation Models: A Comparison," *European Economic Review,* 41, 1201-1249.

Clarida, Richard and Mark Gertler(1997), "How the Bundesbank Conducts Monetary Policy," in *Reducing Inflation: Motivation and Strategies,* Christina and David Romer editors.

Clarida, Richard, Jordi Gali, and Mark Gertler, (1997a), "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," unpublished manuscript

Clarida, Richard, Jordi Gali, and Mark Gertler (1997b): "The Science of Monetary Policy," unpublished manuscript.

Erceg, Christopher J., Dale W. Henderson and Andrew Levin (1998), "Output-Gap and Price Inflation Volatilities: Reaffirming Tradeoffs in an Optimizing Model," mimeo, Federal Reserve Board.

Fuhrer, Jeffrey C., and George R. Moore (1995): "Inflation Persistence", *Quarterly Journal of Economics*, No. 440, February, pp 127-159.

Fuhrer, Jeffrey C. (1997): "The (Un)Importance of Forward-Looking Behavior in Price Specifications," *Journal of Money, Credit, and Banking* 29, no. 3, 338-350.

Fischer, Stanley, (1997): "Long Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," *Journal of Political Economy* 85, 163-190.

Galí, Jordi (1998): "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?," *American Economic Review*, forthcoming.

Ghezzi, Piero, (1997), "Backward Looking Indexation, Credibility and Inflation Persistence," John Hopkins University, mimeo.

Goodfriend, Marvin, and Robert King (1997): "The New Neoclassical Synthesis and the Role of Monetary Policy" *NBER Macroeconomics Annual*, forthcoming.

Gordon, Robert J.(1996), "Time-Varying NAIRU and its Implications for Economic Policy, *NBER Working Paper No. 5735.*

Jeanne, Olivier, (1998), "Generating Real Persistent Effects of Monetary Shocks: How Much Nominal Rigidity Do We Really Need?" *European Economic Review* no. 6, 1009-1032.

Kiley, Michael T.(1997), "Staggered Price Setting and Real Rigidities," Federal Reserve Board FEDS working paper no. 1997-46.

King, Robert G., and Alexander L. Wolman, (1996): "Inflation Targeting in a St. Louis Model of the 21st Century" *NBER Working Paper No. 5507.*

King, Robert G. and Alexander L. Wolman, (1998): "What Should The Monetary Authority Do When Prices Are Sticky?" forthcoming in *Monetary Policy Rules,* J. Taylor, ed, The University of Chicago Press.

King Robert G. and Mark Watson (1994), "The Post-War U.S. Phillips Curve: A Revisionist Econometric History," *Carnegie-Rochester Conference on Public Policy, 157-219.*

Lown Cara S. and Robert W. Rich (1997), "Is There An Inflation Puzzle," *Federal Reserve Bank of New York Quarterly Review, 51-69.*

McCallum, Bennett T., and Edward Nelson (1998): "Performance of Operational Policy Rules in an Estimated Semi-Classical Structural Model," forthcoming in *Monetary Policy Rules,* J. Taylor, ed, The University of Chicago Press.

Roberts, John M. (1997): "Is Inflation Sticky? ", *Journal of Monetary Economics*, No. 39, pp 173-196.

Roberts, John M. (1998): "Inflation Expectations and the Transmission of Monetary Policy," mimeo, Federal Reserve Board.

Rotemberg, Julio, and Michael Woodford (1997a): "An Optimization-Based Econometric Framework for the Evolution of Monetary Policy," mimeo

Rotemberg, Julio and Michael Woodford (1997b): "Interest Rate Rules in a Estimated Sticky Price Model," mimeo, Princeton University.

Sbordone, Argia, M., "Prices and Unit Labor Costs: Testing Models of Pricing," mimeo, Princeton University.

Svensson, Lars E. O., (1997a), "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets", *European Economic Review* 41, June, pp. 1111-47.

Svensson, Lars E. O., (1997b), "Inflation Targeting: Some Extensions", *NBER Working Paper No. 5962*, March.

Taylor, John B. (1980): "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, 88, 1-23.

Watson, Mark, (1993). "Measures of Fit For Calibrated Models," *Journal of Political Economy,* 101-1041.

Woodford, Michael (1996): "Control of the Public Debt: A Requirement for Price Stability?", *NBER Working Paper No. 5684*, July .

Yun, Tack (1996): "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles", *Journal of Monetary Economics*, No. 37, 1996, pp 345-370.

Table 1. Structural Model: Baseline Estimates

Nonfarm Business, 1960:1-1996:4

	β	θ	ω	γ_b	γ_f	λ	p
Basic	0.836 (0.051)	0.806 (0.021)	0.228 (0.055)	0.226 (0.045)	0.671 (0.039)	0.048 (0.012)	0.543
$\beta = 1$	1.000	0.808 (0.026)	0.188 (0.059)	0.189 (0.049)	0.810 (0.025)	0.029 (0.009)	0.525
Reduced Form	-	-	-	0.404 (0.063) -	0.552 (0.064)	0.020 (0.010)	0.999

Table 2. Structural Model: Robustness Analysis

	β	θ	ω	$\mu - 1$	ϕ	γ_b	γ_f	λ	p
Increasing Returns	0.841	0.804	0.202	-0.002	-	0.206	0.689	0.051	0.657
	(0.046)	(0.019)	(0.049)	(0.093)		(0.042)	(0.036)	(0.012)	
	1.000	0.853	0.137	-0.277	-	0.138	0.861	0.018	0.987
		(0.043)	(0.121)	(0.370)		(0.109)	(0.049)	(0.010)	
Extra Inflation Lags	0.870	0.799	0.293	-	0.009	0.276	0.654	0.040	0.373
	(0.105)	(0.048)	(0.098)		(0.059)	(0.075) -	(0.049)	(0.011)	
	1.000	0.766	0.266	-	0.064	0.257	0.742	0.038	0.430
		(0.031)	(0.076)		(0.024)	(0.058)	(0.036)	(0.010)	
Comp. Labor Share	0.945	0.866	0.214	-	-	0.200	0.764	0.017	0.600
	(0.040)	(0.022)	(0.061)			(0.047)	(0.030)	(0.006)	
	1.000	0.858	0.187	-	-	0.179	0.820	0.015	0.720
		(0.025)	(0.063)			(0.050)	(0.024)	(0.005)	

Table 3. Subsample Stability

	β	θ	ω	γ_b	γ_f	λ	p
60:1-79:4	0.887 (0.046)	0.746 (0.029)	0.236 (0.051)	0.245 (0.043)	0.688 (0.032)	0.067 (0.016)	0.787
	1.000	0.736 (0.028)	0.223 (0.048)	0.232 (0.041)	0.767 (0.028)	0.056 (0.013)	0.865
70:1-89:4	0.577 (0.105)	0.724 (0.024)	0.313 (0.034)	0.332 (0.029)	0.444 (0.071)	0.116 (0.027)	0.853
	1.000	0.709 (0.027)	0.226 (0.056)	0.241 (0.045)	0.758 (0.025)	0.069 (0.018)	0.860
80:1-96:4	0.851 (0.060)	0.833 (0.012)	0.025 (0.069)	0.030 (0.078)	0.828 (0.069)	0.055 (0.008)	0.824
	1.000	0.815 (0.012)	-0.065 (0.052)	-0.087 (0.076)	1.087 (0.019)	0.048 (0.009)	0.888

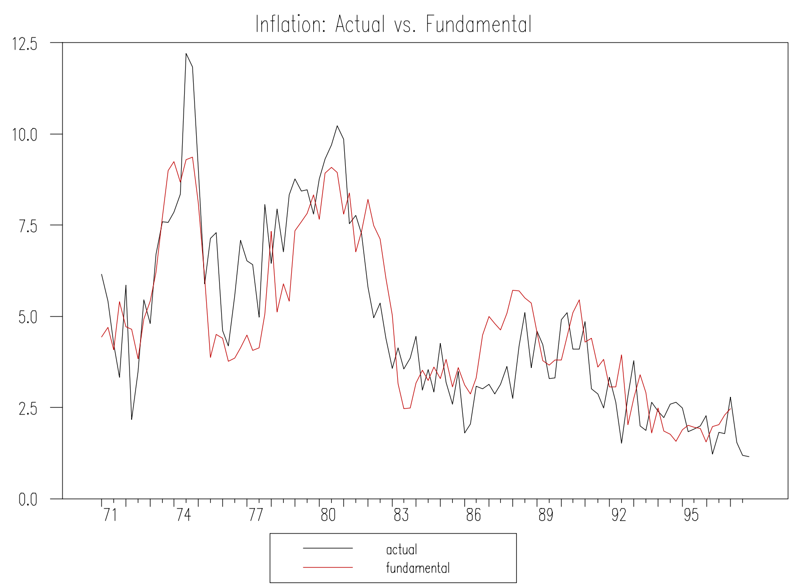
Inflation: Actual vs. Fundamental
12.5
10.0
7.5
5.0
2.5
0.0
71
74
77
80
83
86
89
92
95
actual
fundamental

Figure 1:

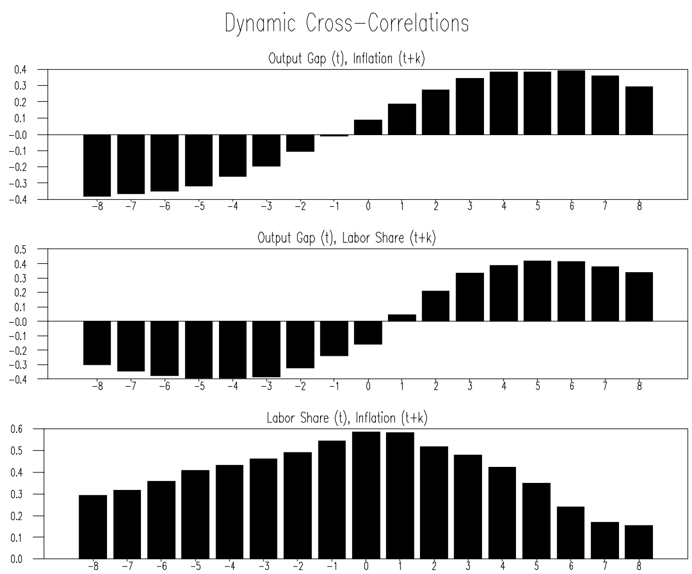
Dynamic Cross-Correlations
Output Gap (t), Inflation (t+k)
Output Gap (t), Labor Share (t+k)
Labor Share (t), Inflation (t+k)

Figure 2: