What Goes Down Must Come Up: Understanding Time-Variation in the NAIRU

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What Goes Down Must Come Up: Understanding Time-Variation in the NAIRU

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Abstract: The behavior of inflation during the 1990s is consistent with the predictions of a model that assumes a constant long-run NAIRU and a constant long-run markup of output prices over unit labor costs. Within this framework, inflation fell during the late 1990s–despite low unemployment–chiefly because an unusually high markup allowed firms to increase wages without raising prices. As the markup returns to normal, the recent unusually favorable unemployment–inflation trade-off can be expected to deteriorate. More generally, movements in the markup induce persistent but ultimately temporary variation in the NAIRU.

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Overview

Based on the favorable inflation experience of the late 1990s, many analysts have concluded that the rate of unemployment that can be maintained without triggering continuing increases in inflation–the so-called "non-accelerating-inflation rate of unemployment," or NAIRU –has fallen by a percentage point or more (Gordon 1997; Staiger, Stock, and Watson 1997a; Meyer 2000). While there are several candidate explanations for this decline, hard evidence favoring one explanation over another is scarce. Consequently, the future course of the NAIRU is highly uncertain. This uncertainty is a serious problem for monetary policy makers, who must take action today based on what they think inflation pressures will be a year or more down the road.

In this paper, I show that a wage-price adjustment model with a constant long-run NAIRU has no difficulty explaining the favorable inflation experience of the 1990s. According to the model, the recent apparent decline in the NAIRU results from an unusually high markup of price over unit labor costs–equivalently, from an unusually low share of wages in income–that has, in turn, been triggered by an acceleration in labor productivity.[1] Unfortunately, the restraint on price growth from a high markup can be expected to wane in the years ahead, as productivity growth levels off. As a result, the unemployment–inflation trade-off will become less favorable.

Although the existing literature on the Phillips curve is extensive, only a small subset of papers looks for a long-run relationship between the price of output and the level of unit labor costs (as opposed to the growth rates of these variables). Moreover, these papers are typically

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[1] The flip side of this phenomenon is noted by Blanchard (2000): "...when underlying total factor productivity growth slows down, it takes some time for both workers and firms to adjust to the new reality. During that time, wages rise too fast relative to total factor productivity growth, leading to a decrease in employment, both directly and through lower profits and lower capital accumulation."

unable to find a cointegrating relationship except when variables besides prices and labor costs are included in the analysis (Mehra 1991, Ghali 1999, Schmidt 2000, Hess and Schweitzer 2000). The problem appears to be a mis-match between the indexes used to track output prices in these studies (the GNP and PCE deflators) and the index used to track unit labor costs (which is based on data from the non-farm business sector). Here, when unit-labor-cost data are drawn from the non-farm business sector, so are the price data. If cost data come from the non-financial corporate sector, price data come from that sector too. The downside of this consistency is that it limits my results to price measures that are somewhat narrower in scope than those used in previous work.

In its finding that the markup is important to understanding aggregate price dynamics, the current paper bears some resemblance to recent work by Gali and Gertler (1999).[2] However, taken literally, the Gali-Gertler model says that in an economy with forward-looking price contracts the *only* variables helpful for predicting future price inflation ought to be lagged price inflation and the markup. Results reported here do not support quite so extreme a position. While lagged price inflation and the markup are indeed valuable inflation indicators, so are productivity growth and the unemployment rate.

The equations estimated here are potentially subject to the Lucas critique: significant

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[2] See also Brayton, Roberts, and Williams (1999). There are two major methodological differences between the current paper and the BRW piece. First, the error correction term in BRW is the markup of price over *trend* unit labor costs rather than actual unit labor costs. Shifts in trends are notoriously difficult to recognize in real time. Second, BRW are exclusively concerned with explaining the dynamics of price inflation–the evolution of labor costs is taken as given. Lacking a wage equation, BRW are unable to pin down the long-run NAIRU or even to rule out the possibility that no stable long-run NAIRU exists. The two analyses were undertaken concurrently and independently.

changes in the conduct of monetary policy might lead to shifts in wage and price setting arrangements that would cause the performance of the estimated equations to deteriorate. However, no such deterioration is yet apparent.[3]

The Model

Motivation. Standard microeconomic theory predicts that perfectly competitive firms will hire labor up to the point where the marginal product of labor equals the real wage. More generally, firms will hire labor up to the point where the money wage equals the marginal revenue product of labor (the marginal product of labor times marginal revenue). If firms face constant-elasticity demand schedules, marginal revenue will be a constant fraction of price, and firms will charge a price that is a constant markup over marginal labor costs. Finally, if the elasticity of output with respect to labor is constant, then the marginal product of labor will be a constant fraction of the average product of labor and firms will charge a price that is a constant markup over unit labor costs. Equivalently, wage payments will be a constant fraction of the value of output.

While it would be unrealistic to expect the markup of price over unit labor costs to be absolutely constant over time (Kimball 1995), one might suspect on the basis of the above argument that this markup is mean-reverting–that it *tends* to a constant over time. Formal statistical tests applied to data from the non-farm-business and non-financial-corporate sectors confirm that one can reject a unit root in the markup at the 10 percent significance level.[4] That

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[3] For a related discussion, see Fuhrer (1995).

[4] Using fourth-quarter, non-farm-business-sector data running from 1956-1999, the Phillips-Perron test statistic is –2.627 and the augmented Dickey-Fuller test statistic is -2.605. Applied to non-financial corporate data (1959:Q4-1999:Q4) the Phillips-Perron and augmented

the markup is stationary suggests that the gap between the current markup and its long-run average must affect the rate of price growth (negatively) and/or the rate of wage growth (positively). However, standard Phillips-curve specifications ignore this error-correction effect. At best, these specifications assume long-run equality between the *growth rates* of output prices and unit labor costs.[5]

Equations. To investigate the role of the error-correction term in wage and price dynamics, I add a lagged value of the price-cost markup to the right-hand sides of otherwise fairly standard price and wage Phillips-curve equations. Specifically, my price and wage adjustment equations are of the general form:

$$\Delta p(t) = \beta(L)\Delta p(t-1) + \gamma(L)\Delta q(t) + \delta(L)\Delta w(t-1) + \alpha_1[u(t-1) - u^*] + \mu_1[m(t-1) - m^*] + \epsilon(t) \quad (1a)$$

$$\Delta w(t) = \beta'(L)\Delta p(t-1) + \gamma'(L)\Delta q(t) + \delta'(L)\Delta w(t-1) + \alpha'_1[u(t-1) - u^*] + \mu'_1[m(t-1) - m^*] + \epsilon'(t). \quad (1b)$$

Here $\Delta p(t)$, $\Delta w(t)$ and $\Delta q(t)$ are the growth rates of output prices, wages and labor productivity at

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Dickey-Fuller tests yield statistics of -2.710 and -2.716, respectively. In each case, a unit root is rejected at the 10 percent significance level.

[5] Gordon (1988), for example, considers (but ultimately rejects) the hypothesis that lagged growth in unit labor costs is helpful in predicting price inflation. Gordon (1999), finds labor-cost growth helpful for predicting GDP inflation, but not PCE inflation.

time t, respectively; $u(t-1)$ and $m(t-1) \equiv p(t-1) + q(t-1) - w(t-1)$ are the level of unemployment and the log-level of the markup of price over unit labor cost at time $t-1$; $\beta(L)$, $\beta'(L)$, $\gamma(L)$, $\gamma'(L)$, $\delta(L)$, and $\delta'(L)$ are polynomials in the lag operator, L; u^*, m^*, α_1, α'_1, μ_1, and μ'_1 are parameters; and $\epsilon(t)$ and $\epsilon'(t)$ are zero-mean, serially uncorrelated errors. Equations 1a and 1b say that price and wage growth depend on lagged growth in wages and prices, current and lagged productivity growth, excess-demand pressures as measured by the lagged unemployment rate and, potentially, the lagged markup of prices over unit labor costs. One would expect to find $\alpha_1, \alpha'_1, \mu_1, \gamma_i \leq 0$ and $\mu'_1, \beta_i, \beta'_i, \delta_i, \delta'_i, \gamma'_i \geq 0.$

In a hypothetical non-stochastic steady state, Equations 1a and 1b imply that

$$\Delta p = \textstyle\sum_i \beta_i \Delta p + \sum_i \gamma_i \Delta q + \sum_i \delta_i \Delta w \qquad (2a)$$

and

$$\Delta w = \textstyle\sum_i \beta'_i \Delta p + \sum_i \gamma'_i \Delta q + \sum_i \delta'_i \Delta w, \qquad (2b)$$

where Δp, Δw, and Δq are steady-state values of price, wage, and productivity growth, respectively. In addition, the real wage rises at the same rate as labor productivity: $\Delta w - \Delta p = \Delta q$. It follows that we must have

$$\textstyle\sum_i \beta_i + \sum_i \delta_i = 1 \qquad (3a)$$

$$\textstyle\sum_i \beta'_i + \sum_i \delta'_i = 1 \qquad (3b)$$

$$\sum_i \gamma_i + \sum_i \delta_i = 0 \tag{3c}$$

$$\sum_i \gamma'_i + \sum_i \delta'_i = 1 \tag{3d}$$

if Equations 2a and 2b are to hold for an arbitrary steady-state inflation rate and rate of productivity growth. Substitute 3a-d into Equations 1a and 1b and rearrange terms to obtain:

$$\Delta^2 p(t) = a(L)\Delta^2 p(t - 1) + b(L)\Delta m(t - 1) + c(L)\Delta^2 q(t) + \alpha_1[u(t - 1) - u^*] + \mu_1[m(t - 1) - m^*] + \epsilon(t) \tag{4a}$$

$$\Delta^2 w(t) = a'(L)\Delta^2 w(t - 1) + b'(L)\Delta m(t - 1) + c'(L)\Delta^2 q(t) + \alpha'_1[u(t - 1) - u^*] + \mu'_1[m(t - 1) - m^*] + \epsilon'(t), \tag{4b}$$

where

$$a_i \equiv - \sum_{j = i + 1}(\beta_j + \delta_j) \leq 0$$

$$a'_i \equiv - \sum_{j = i + 1}(\beta'_j + \delta'_j) \leq 0$$

$$b_i \equiv - \delta_i \leq 0$$

$$b'_i \equiv \beta'_i \geq 0$$

$$c_i \equiv - \sum_{j = i + 1}(\gamma_j + \delta_j)$$

$$c'_i \equiv \sum_{j = i + 1}(\beta'_j - \gamma'_j).$$

Note that the order of the polynomial $a(L)$ is one less than the maximum of the orders of $\beta(L)$

and $\delta(L)$. Similarly, the orders of the polynomials $a'(L)$, $c(L)$, and $c'(L)$ are reduced by one relative to the orders of $\beta'(L) + \delta'(L)$, $\gamma(L) + \delta(L)$, and $\beta'(L) - \gamma'(L)$, respectively.

Equations 4a and 4b have two advantages relative to Equations 1a and 1b. First, the long-run constraints 3a-d are incorporated directly into the equations and, so, do not need to be imposed separately. Second, *changes* in the growth rates of wages, prices, and productivity are more likely to be stationary than are the growth rates themselves.[6] Hence, the potential for bias in the reported standard errors of the estimated coefficients is reduced.

Estimating the Model

Data and Methodology. I use the civilian unemployment rate to measure labor market slack.[7] Price, wage, and productivity data are from the non-farm-business and non-financial-corporate sectors. The non-farm business sector accounts for 84 percent of GDP. Unfortunately, in some of the included industries–such as government enterprises and the services to owner-occupied housing–the strength of the profit maximization motive is suspect or the production technology is distinctive (Nordhaus 1997). The non-financial corporate sector accounts for only 56 percent

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[6] For the data used in this paper (described below), Phillips-Perron and augmented Dickey-Fuller tests applied to the first differences of wages and prices fail to reject a unit root at the 10-percent significance level. In the case of productivity growth, a unit root is rejected at the 1-percent significance level. However, it is generally acknowledged that there was a large and sustained downward shift in productivity growth beginning in the late 1960s or early 1970s and an upward shift sometime in the 1990s. Applied to second-difference wage, price, and productivity data, the tests in each case reject a unit root at better than the 1-percent significance level.

[7] Using the unemployment rate for prime-age males to measure labor-market slack somewhat improves the fit of the equations, but does not importantly alter the results. See the section headed "Stability and Robustness," below.

of GDP, but does less mixing of apples and oranges. Estimation is accomplished by applying seemingly unrelated regression (SUR) to Equations 4a and 4b.

For the non-financial corporate sector, the wage, price, and productivity data span the period from 1959 through 1999. The sample period I use for the non-farm business sector extends back a few years further, to 1956. Only fourth-quarter data are used in the estimations, partly to avoid complicating the model and partly because a forecast horizon of a year or more is most relevant for policy.[8] I use four lags each of wage, price, and productivity growth in the unconstrained model (Equations 1a and 1b), so that the polynomials *a(L)* and *a'(L)* in Equations 4a and 4b are of order three, while the polynomials *b(L)*, *b'(L)*, *c(L)*, and *c'(L)* are of order four. Finally, terms involving u^* and m^* are combined and treated as a constant in each equation and a Nixon wage-price-control dummy variable is included among the right-hand-side variables.[9]

Results: Non-Financial Corporate Sector. Results for the non-financial corporate sector are presented in Column 1 of Table 1. In the price equation (Table 1A), there is clear evidence of an error-correction effect: inflation is lower the higher is the lagged ratio of price to unit labor cost. Otherwise the results are quite conventional. High lagged unemployment and increases in productivity growth act to restrain inflation. If inflation rose last year, there is a tendency for it to fall this year. Consistent with Gordon (1988), the influence of lagged markup growth on

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[8] The analysis assumes that the lag with which a change in productivity growth impacts inflation is the same regardless of the underlying source of the change. This assumption becomes more and more unrealistic as the sampling interval is shortened.

[9] This variable was defined to equal 0.5 in 1971, 1.0 in 1972 and 1973, -2.5 in 1974, and zero everywhere else.

inflation is small: the relevant Wald joint test statistic has a marginal significance level of 0.454. Moreover, the coefficients attached to these terms have counterintuitive signs.

The wage-inflation results (Table 1B) differ from those for price inflation in two key respects. First, the sign of the markup error-correction coefficient is opposite that which one would have expected. Second, current and lagged changes in productivity growth have a negligible impact on wage inflation after controlling for lagged growth in the markup. (Their joint marginal significance level is 0.220.)

Column 2 of Tables 1A and 1B present results obtained when lagged markup growth is dropped from the price equation, changes in productivity growth are dropped from the wage equation, and the Nixon dummy variable (which doesn't appear to play a significant role in either equation) is eliminated entirely. Results are very much the same as before, except the markup error-correction term is now statistically insignificant in the wage equation. If (as in Column 2') this term is dropped, the lagged markup growth terms also become insignificant. (Their joint marginal significance level is 0.299.) Hence, the data suggest that price and wage inflation dynamics are well described by equations of the form

$$\Delta^2 p(t) = a(L)\Delta^2 p(t-1) + c(L)\Delta^2 q(t) + \alpha_1 u(t-1) + \mu_1 m(t-1) - (\alpha_1 u^* + \mu_1 m^*) + \epsilon(t) \quad (5a)$$

and

$$\Delta^2 w(t) = a'(L)\Delta^2 w(t-1) + \alpha'_1 u(t-1) - \alpha'_1 u^* + \epsilon'(t), \quad (5b)$$

respectively. Equation 5b is an entirely conventional wage Phillips curve in which wage growth changes are related to lagged wage growth changes and the unemployment rate. Equation 5a would be a conventional price Phillips curve were it not for the markup error-correction term.

Simultaneous estimates of Equations 5a and 5b are presented in Column 3. Coefficient estimates change little if the sample is truncated in 1989 (Column 4), or if the price and wage equations are estimated separately, by ordinary least squares (Column 5).

An important conclusion emerging from the results displayed in Table 1 is that price dynamics are not independent of wage developments. Wages and productivity together determine the level of unit labor costs, and the level of unit labor costs affects price inflation with a lag through the markup error-correction term. The effect is fairly large: for each percentage point that the markup exceeds its long-run value there is a 32-basis-point deceleration in price inflation the following year. There is no similar dependence of wage dynamics on price developments.

Not just the level of productivity, but also changes in productivity growth have a strongly negative impact on price inflation. In particular, a 1-percentage-point increase in productivity growth implies a 42-basis-point immediate decline in price inflation and an additional 33-basis-point decline a year later. Productivity growth changes have no similar impact on wage inflation.

An estimate of the long-run NAIRU can be obtained by dividing the constant term in Equation 5b by the coefficient of $u(t - 1)$. Using the full-sample coefficient estimates displayed in Column 3, this calculation yields $u^* = 0.0609$ with standard error 0.0026. Similarly, the pre-1990 results displayed in Column 4 imply that $u^* = 0.0607$ with standard error 0.0036. Thus, the long-run NAIRU is tightly estimated and shows no sign of having fallen during the 1990s.[10]

Results: Non-Farm Business Sector. Tables 2A and 2B are the non-farm-business counterparts of Tables 1A and 1B. Column 1 displays estimates of the price and wage adjustment equations in their most general form (Equations 4a and 4b). Note that here, as in Table 1, a significant markup error-correction effect is evident in the price equation. The coefficient of the error-correction term in the wage equation, however, is statistically and quantitatively insignificant.

Again, some simplification of the equations appears feasible. In Column 1 of Table 2, just as in Column 1 of Table 1, every productivity growth term is statistically insignificant in the wage equation and the markup growth terms are collectively insignificant in the price equation. (One markup growth term is individually significant in the price equation, but has a counterintuitive sign.) Column 2 of Table 2 drops these terms from the non-farm business equations, just as Column 2 of Table 1 dropped them from the non-financial corporate equations. The change in specification does not alter the main result from Column 1, that the markup error-correction term plays an important role in the price equation but not in the wage equation.

Column 3 of Table 2 further simplifies the non-farm-business price and wage equations by eliminating both the markup level and the second through fourth lags of markup growth from the wage equation and all but the contemporaneous change in productivity growth from the price equation. In their new, stripped-down form the estimated equations are:

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[10] The standard error is calculated using the delta method. Monte Carlo results obtained by Staiger, Stock, and Watson (1997b) suggest that a two-standard-error band calculated using the delta method delineates a 90-percent confidence interval around the estimated NAIRU.

$$\Delta^2 p(t) = a(L)\Delta^2 p(t-1) + c_0\Delta^2 q(t) + \alpha_1 u(t-1) + \mu_1 m(t-1) - (\alpha_1 u^* + \mu_1 m^*) + \epsilon(t) \qquad (6a)$$

and

$$\Delta^2 w(t) = a'(L)\Delta^2 w(t-1) + b'_0\Delta m(t-1) + \alpha'_1 u(t-1) - \alpha'_1 u^* + \epsilon'(t), \qquad (6b)$$

respectively.

Like its corporate cousin (Equation 5a), Equation 6a would be a conventional Phillips curve were it not for the markup error-correction term on its right-hand side. This error-correction effect is statistically significant in the non-farm business sector, just as it was in the non-financial corporate sector, but the point estimate of the coefficient is smaller in magnitude.

Comparing the wage equations for the non-financial-corporate and non-farm business sectors, the only important difference is that non-farm-business wage dynamics are not entirely independent of price developments. Through markup growth, last year's growth in nominal output per hour exerts a statistically significant (positive) influence on current wage growth in the non-farm business sector, but not in the non-financial corporate sector.

Coefficient estimates change little when Equations 6a and 6b are estimated over a sample period that excludes the 1990s (as in Column 4) or when the two equations are estimated independently by ordinary least squares (as in Column 5).

What of the long-run NAIRU? Consistent with results reported above for the non-financial corporate sector, the estimate of the long-run NAIRU implicit in the regression results of Table 2, Column 3 is 5.98 percent with a standard error of 0.23 percentage points. When the

1990s are excluded from the sample (Column 4), the estimated long-run NAIRU is 6.00 percent with a standard error of 0.27 percentage points.

Stability and Robustness

The fact that the estimated coefficients of Equations 5a&b and 6a&b don't change very much when sample periods are shortened to exclude the 1990s is encouraging, but hardly conclusive. In this section, I present results from several additional stability and robustness tests. Generally, these results are favorable to the markup error-correction model of price and wage adjustment developed above.

Residuals Tests. The residuals of the price- and wage-inflation equations were examined for evidence of serial correlation, outliers, and systematic bias. Such evidence would suggest that the equations might be mis-specified. In fact, the residuals appear to be generally well behaved.

Table 3 reports marginal significance levels for three tests of up to fourth-order serial correlation.[11] In no case does serial correlation appear to be a problem.

Figures 1A&B and 2A&B show plots of the recursive residuals for each equation, along with two-standard-error bands. The bands are violated in only a few instances, only in the non-farm business sector, and only well prior to the 1990s. That an occasional residual differs from zero by more than two standard errors is, of course, to be expected.

Finally, Figures 3A&B and 4A&B show plots of the cumulative sum of recursive

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[11] Ljung-Box Q statistics were calculated at lag lengths ranging from 1 to 16 with consistently negative results. The specific results reported in the table are typical.

residuals for each equation, along with 5-percent significance bounds. In no case are the bounds broached, indicating that the equations do not consistently over- or under-predict changes in inflation as the sample period over which they are estimated is extended.

Tests of Coefficient Stability. Recursive coefficient estimates for each equation are displayed in Figures 5A&B and 6A&B. There is some evidence that the unemployment rate became more important as a determinant of non-financial-corporate price inflation during the late 1970s and early 1980s, but coefficient estimates otherwise remain quite stable as sample periods are extended. In particular, all coefficient estimates hold steady as data from the 1990s are brought to bear.

Robustness to Changes in Specification. Tables 4A, 4B, 5A, and 5B consider various changes to the specifications of the price and wage inflation equations, including the introduction of relative price shocks and alternative measures of labor-market slack. In addition, the tables present coefficient estimates obtained when an oil-supply-disruption variable is used as an instrument for the current change in productivity growth, to guard against the possibility that innovations to productivity growth may be correlated with the error term in the price equation. Results reveal that marginal improvements to the baseline model are possible, but do not affect the quantitative and statistical significance of the markup-error-correction term.

The first column of coefficient estimates in Tables 4 and 5 is from the baseline model specification (Equations 5a and 5b for the non-farm corporate sector and 6a and 6b for the non-farm business sector), and is identical to Column 3 of Tables 1 and 2. To obtain the second column of coefficient estimates, I modified the baseline model by adding a lagged value of the average duration of unemployment [*dur(t - 1)*]to the right-hand sides of the price and wage equations. Duca (1996) argues that unemployment duration has significant marginal explanatory power for wage and price inflation–especially the low and declining inflation of the mid 1990s. Whatever its theoretical merits as a measure of labor-market slack, however, in the present context duration adds nothing to the performance of the baseline model. In contrast, the markup error-correction term remains highly statistically significant in both Equation 5a and Equation 6a.

Next, I tried adding the lagged unemployment rate of prime-age males [*mu(t - 1)*] to the price and wage inflation equations in an effort to control for possible shifts in the NAIRU due to changes in the demographic composition of the labor force. In the wage equations (5b and 6b), the unemployment rate for prime-age males is unambiguously superior to the overall unemployment rate as a measure of excess supply. (See the third column of results reported in Tables 4B and 5B.) In the price-inflation equations (5a and 6a), in contrast, the choice of unemployment rate makes almost no difference: neither rate dominates the other (Tables 4A and 5A, Column 3). Meanwhile, the markup error-correction term remains highly statistically significant in the price equations, with an estimated coefficient that is virtually unchanged from its baseline value.

The relative price of oil is often included as a right-hand-side variable in Phillips-curve equations. In a model that already includes productivity growth as an explanatory variable, the best rationale for separate inclusion of the price of oil is that the timing of the inflation impact of a productivity-growth change may be sensitive to the underlying cause of the change.[12] Alternatively, workers may increase their wage demands if they see energy prices rising.[13] In Tables 4 and 5, the fourth column of coefficients shows what happens when the contemporaneous change in the price of oil relative to the price of output [$\Delta o(t)$] is added to the right-hand sides of the baseline price and wage equations. Results are mixed. In the non-financial corporate sector, the magnitude of the oil-price coefficient is the same in the price and wage equations, but the coefficient is statistically significant only in the wage equation. In the non-farm business sector, oil-price changes have a statistically and quantitatively significant impact only on price inflation. In both sectors, the markup error-correction term remains a highly statistically significant influence on price inflation.

As discussed much earlier in this paper, a wage-taking firm will try to maintain a constant markup of product price over unit labor costs. However, it's conceivable that the short-run dynamics of wages are influenced by consumer prices in addition to or instead of product prices. After all, it is presumably the value of wages measured in consumer goods that concerns workers. Unit-root tests applied to the log ratio of price index for personal consumption expenditures to the implicit output price deflator strongly suggest that it has a stationary growth rate.[14] Using this result (and applying the same reasoning by which Equations 4a&b were derived from Equations 1a& b and 2a&b), one can show that if the PCE price index matters for

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[12] Other relative-price changes that are sometimes included as right-hand-side variables in Phillips-curve regressions are changes in food prices, import prices, and health-care prices.

[13] This explanation presumes that workers have some market power.

[14] The Phillips-Perron test rejects a unit root at the 1-percent level in both the non-financial-corporate and non-farm-business sectors.

wage inflation it ought to matter only through lagged growth in the markup of the PCE price over unit labor costs, much as lagged product-price inflation enters Equation 4b only through lagged growth in the markup of product prices over unit labor costs.

The columns headed "PCE Price" in Tables 4 and 5 show what happens when four lagged PCE markup growth terms [$\Delta m'(t - i)$ i = 1, 2, 3, 4] are added to the right-hand sides of Equations 5b and 6b to test for a possible impact of consumer price inflation on the short-run dynamics of wage inflation. The coefficient estimates suggest that no consumer-price impact is operative. In the non-financial corporate sector (Table 4B), the lagged PCE markup growth terms are both individually and collectively insignificant.[15] In the non-farm business sector (Table 5B), only one lagged PCE markup growth term is statistically significant, and its sign is counterintuitive. (The negative sign on the coefficient implies that rapid growth in consumer prices tends to *depress* subsequent wage growth.) Collectively, the PCE markup growth terms have a marginal significance level of 0.218. Meanwhile, the estimates of the markup error-correction coefficients in the price-inflation equations are robust both in magnitude and statistical significance. (See the next-to-last columns of Tables 4A and 5A.)

The baseline price-inflation equations include the contemporaneous change in productivity growth as a right-hand-side variable. To guard against possible coefficient bias due to endogeneity, I re-estimated the price-inflation equations using instrumental variables. Instruments include all of the lagged variables appearing on the right-hand sides of the price- and wage-inflation equations and a variable meant to capture disruptions to the supply of oil. Major oil-price shocks can reasonably be assumed to be exogenous, and yet are likely to be correlated

[15] A test of hypothesis that all four coefficients equal 0 has marginal significance 0.857.

with changes in the growth rate of productivity. The oil-shock variable was defined to be the difference between the current real price of oil (the nominal oil price deflated by the output-price index for the non-financial-corporate or non-farm-business sector) and a three-year average of lagged real oil prices when this difference was positive, and zero otherwise. Previous research strongly suggests that oil-price increases that don't simply reverse recent decreases have a much more powerful impact on the real economy than do other oil-price changes (Hamilton 2000).[16]

Plots of the oil-shock variables for the non-financial-corporate and non-farm-business sectors are displayed in Figure 7. They show large upward spikes in 1974, 1979-80, and 1990, and smaller spikes in 1996 and 1999. Coefficient estimates from the instrumental variables regressions are displayed in the final columns of Tables 4A and 5A. In the non-financial corporate sector (Table 4A), the coefficients attached to lagged changes in price inflation and lagged changes in productivity growth are notably larger in the instrumental variables regression results than in the baseline results. In the non-farm business sector (Table 5A), in contrast, there is very little difference between the baseline and instrumental-variable coefficient estimates.[17] Regardless of the sector examined, the coefficient attached to the markup error-correction term, *m(t - 1)*, appears to be robust with respect to the instrumental variables methodology.[18]

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[16] I confirmed this finding by regressing productivity-growth changes on both upward and downward movements in real oil prices relative to a three-year average of oil prices. Only upward oil-price movements were found to have significant explanatory power for changes in productivity growth.

[17] In the non-farm business sector, a Hausman test fails to reject the exogeneity of the current change in productivity growth at even the 10-percent significance level. In the non-financial corporate sector, however, exogeneity is rejected at the 5-percent level.

[18] Very similar results are obtained if the sample period is cut short in 1995, prior to the 1996 and 1999 oil-price increases. Hamilton (2000) speculates that only oil-price increases triggered by military conflict in the Middle East are relevant to U.S. real economic activity. (Or,

The bottom line is that, although there may be room for marginal improvements to the baseline inflation equations, such improvements do not appear to diminish the importance of the markup error-correction term for understanding output-price dynamics.

Why Has the U.S. Economy's Inflation Performance Been So Good?

In this section, I provide two complimentary perspectives on the behavior of price inflation in the U.S., with particular focus on the role of the markup in the 1990s. I begin by comparing the out-of-sample performance of the markup model with that of an otherwise-identical model without the markup error-correction term. Then I show that a short-run or time-varying NAIRU is implicit in the markup model, and discuss how its properties differ from those of time-varying NAIRUs estimated by Gordon (1997) and Stock and Watson (1997a,b).

The Role of the Markup: A First Look. As noted above, the price-inflation equations estimated here differ from conventional Phillips-curve equations only in that they include error-correction terms, equal to the markup of price over unit labor costs, on their right-hand side. How important is this term for understanding the favorable inflation experience of the 1990s? To see, I ran dynamic, out-of-sample simulations of the wage-price markup model and an otherwise identical model with the error-correction term deleted.[19] Each model was estimated by

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at least, only such increases are truly *exogenous* with respect to U.S. economic activity.) If Hamilton's conjecture is correct, then the 1996 and 1999 price increases should not be included in the set of oil-price shocks.

[19] In constructing out-of-sample predictions of price inflation, the lagged price and price-inflation data that enter on the right-hand-side of the price equations (including those which feed into the markup) are numbers generated by the price equations themselves. Actual data are used

SUR using data through 1989, and was simulated over the ten-year period from 1990 through 1999.

Results for the non-financial corporate sector are displayed in Figure 8A (price inflation) and Figure 8B (wage inflation). In each diagram, the solid line is actual inflation, the long-dashed line shows inflation predicted by the markup model, and the short-dashed line shows inflation predicted by the traditional Phillips-curve model. The price-inflation predictions of the two models are fairly similar through 1995, but then diverge noticeably. While the traditional model overpredicts inflation in every year from 1994 on–by amounts that increase with time–the markup model stays pretty much on track. By 1999, the inflation predictions of the two models differ by 125 basis points. The markup model actually *under*predicts price inflation by 25 basis points, while the traditional model overpredicts by 100 basis points. Clearly, the markup model produces a superior out-of-sample performance: that inflation fell during the late 1990s, despite a low unemployment rate, is no puzzle once one factors in the influence of the markup.

The wage-inflation equations of the markup and conventional models are identical in form. However, coefficient values differ slightly, because the wage equations are estimated jointly with differently specified price equations. Since the differences in the wage-equation coefficient estimates are small, so are the differences in the two models' wage-inflation predictions (Figure 8B). The models both markedly underpredict wage inflation in 1990, but do a reasonably good job thereafter.

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for all other right-hand-side variables. Similarly, in constructing out-of-sample predictions of wage inflation, lagged wage-inflation data are generated by the wage equations themselves, while price, productivity, and unemployment data are actual.

Results for the non-farm business sector (displayed in Figures 9A&B) are qualitatively similar to those for the non-financial corporate sector. The markup and traditional models predict price inflation about equally well through 1994, but thereafter the gap between predicted and actual inflation widens sharply for the traditional model, while the errors made by the markup model remain small (Figure 9A). By 1999, the traditional model overpredicts price inflation by 280 basis points. The markup model overpredicts price inflation by only 90 basis points. The difference is striking, and suggests that unusually high markups have exerted an important restraining influence on price inflation in the non-farm business sector during the 1990s.

What of wage inflation? Again, the simulated wage-inflation equations differ from one another only because they are estimated jointly with differently specified price-inflation equations. As shown in Figure 9B, the two models do a good job of tracking actual wage inflation over the 1990s as a whole. However, both fail to explain a big decline in wage inflation that occurred in 1993. An absence of wage pressures was widely noted during the mid 1990s, and attributed to unusually strong feelings of job insecurity (Greenspan 1996).

The Markup as a Source of Short-Run Variation in the NAIRU. The failure of output prices to accelerate during the 1990s has led many analysts to speculate that the NAIRU has fallen. Such speculation treads potentially dangerous ground: one doesn't want to get into the position of invoking a NAIRU shift whenever inflation doesn't behave quite as expected. If the NAIRU is to be a useful construct, its movements must be directly observable or, alternatively, limited in size and/or frequency. Recent prominent models of time-variation in the NAIRU by Gordon

(1997) and Staiger, Stock and Watson (1997a,b) have taken the second approach. Rather than try to *explain* movements in the NAIRU, they have *inferred* variation from the behavior of inflation, subject to certain smoothness restrictions.[20] Thus, Gordon (1997) and Staiger, Stock and Watson (1997b) use the Kalman filter to estimate the path followed by the NAIRU under the assumption that NAIRU changes are white noise with a specified variance. The variance is chosen so as to rule out sharp zig zags in the NAIRU. Similarly, Staiger, Stock and Watson (1997a,b) assume that the NAIRU can be modeled as a cubic spline with several knot points. The estimated inflation equations in these analyses differ from conventional Phillips curves only in that they have time-varying intercepts.

In contrast to the existing literature, this paper advances the proposition that apparent time-variation in the NAIRU is the result of observable movements in the markup of price over unit labor costs. Specifically, the time-varying NAIRU (TV-NAIRU) implicit in the markup model is[21]

$$u^*_{TV}(t) \equiv u^* - (\mu_1/\alpha_1)[m(t) - m^*]. \tag{7}$$

Note that whether the path of u^*_{TV} is smooth or full of zigs and zags is determined by whether the

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[20] Gordon (1999), on the other hand, attempts to explain recent declines in inflation using a variety of relative-price shocks and methodological changes.

[21] Using this definition, Equations 5a and 6a take the form of a conventional Phillips curve with a time-varying intercept:

$$\Delta^2 p(t) = a(L)\Delta^2 p(t-1) + c(L)\Delta^2 q(t) + \alpha_1[u(t-1) - u^*_{TV}(t-1)] + \epsilon(t).$$

path of the markup is itself smooth or uneven. Moreover, since both theory and the empirical evidence suggest that the ratio of price to unit labor cost is mean reverting, u^*_{TV} tends to a constant value over time: in contrast to Gordon's random-walk TV-NAIRU, a favorable unemployment–inflation trade-off today need not lead one to expect a similarly favorable trade-off in the future. Finally, u^*_{TV} differs from the TV-NAIRUs developed by Gordon and Staiger, Stock and Watson in that its evolution is endogenous. Today's value of u^*_{TV} is a function of past wage, price and productivity growth–all variables that are potentially affected by policy.

Plots of u^*_{TV} and the actual unemployment rate are displayed in Figure 10 (for the non-financial corporate sector) and Figure 11 (for the non-farm business sector). The two figures are broadly similar to one another. They both show strong inflation pressures in the late 1960s and early 1970s; deflation pressures in the mid 1970s, the first half of the 1980s, and the first half of the 1990s; and the emergence of inflation pressures again in the last few years of the 1990s. Both versions of u^*_{TV} show a trough in 1965, prominent peaks around 1969-70, 1973-4, and 1979-80, and smaller peaks around 1986 and 1990-1.[22] However, the non-financial-corporate u^*_{TV} tends to be somewhat lower than the non-farm-business u^*_{TV} in the 1960s, and somewhat higher in the 1990s. As of 1999, u^*_{TV} was 5.3 percent when calculated using non-financial-corporate data, and 4.8 percent using non-farm-business data.

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[22] The 1960:Q4 spike in the non-farm business-sector TV-NAIRU is anomalous. It corresponds to an outlier in the non-farm business markup, and immediately precedes a 1961 outlier in the change in productivity growth. Both outliers are explained away if some of the productivity gains officially recorded in 1961 actually took place in 1960. Fortunately, the coefficient on the markup and the coefficient on the current change in productivity growth are similar in magnitude in Equation 6a. As a result, minor timing errors in recorded productivity growth are of little real consequence for predicting inflation. For example, the sharp increase in productivity growth recorded in 1961 leads the model to correctly predict a fall in inflation, despite the fact that $u < u^*_{TV}$ in 1960:Q4.

Figures 12 and 13 compare the behavior of u^*_{TV} to that of random-walk TV-NAIRUs. The latter are obtained by applying the Kalman filter to versions of Equations 5a and 6a in which the markup error-correction coefficient is set equal to 0. Consistent with Gordon (1997), innovations to the random-walk TV-NAIRU are assumed to have a standard deviation of 0.4 percentage points (the Q4-over-Q4 equivalent to Gordon's 0.2-percentage-point quarterly standard deviation). Over the portion of the sample period that the markup and random-walk measures overlap, their movements are quite similar. In the non-financial corporate sector, even the correlation between year-to-year changes in the two TV-NAIRUs is fairly strong; while in the non-farm business sector, the random-walk TV-NAIRU behaves rather like a 5-year moving average of u^*_{TV}.[23] The bottom line is that changes in the markup seem to explain most of the Phillips-curve shifts identified by the Kalman filter, not just in the 1990s, but also in the 1970s and 1980s.[24]

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[23] In the non-financial corporate sector, the correlation between u^*_{TV} and the random-walk TV-NAIRU is 0.63. The correlation between year-to-year changes in u^*_{TV} and year-to-year changes in the random-walk TV-NAIRU is 0.38. This correlation rises to 0.47 if u^*_{TV} is replaced by its own 3-year centered moving average before the year-to-year change is calculated. In the non-farm business sector, the correlation between u^*_{TV} and the random-walk TV-NAIRU is 0.65. The correlation in year-to-year changes is only 0.25, but rises to 0.35 when u^*_{TV} is replaced by its own 5-year centered moving average.

Even though one can reject a unit-root in u^*_{TV} over the full sample, movements in u^*_{TV} are sufficiently persistent and sufficiently correlated with movements in the random-walk TV-NAIRU that the two series appear to be cointegrated over that portion of the sample where they overlap. In the non-financial corporate sector, a unit root in the difference between u^*_{TV} and the random-walk TV-NAIRU is rejected at the 1-percent level by both the Phillips-Perron and Augmented Dickey-Fuller tests. In the non-farm business sector, a unit root is rejected at the 5-percent level by the Phillips-Perron test and at the 1-percent level by the Dickey-Fuller test.

[24] Reflecting the high correlation between the two TV-NAIRUs, when I tried applying the Kalman filter to price equations that included the markup, I was unable to obtain convergence.

Concluding Remarks

Economic theory tells us that a profit-maximizing firm will, under reasonable conditions, charge a price that is a constant markup over unit labor costs. Although real-world aggregate markup measures are certainly *not* time invariant, the data suggest that they *are* mean stationary–a result that has useful implications for aggregate price adjustment. In particular, price inflation appears to be sensitive to the level of the markup. When the markup is unusually low, inflation rises as firms try to rebuild their profit margins. When the markup is unusually high, inflation falls due to competitive pressures. These effects are of substantial help in explaining why inflation drifted lower in the mid and late 1990s despite a low unemployment rate.

Increases in productivity growth tend to raise the markup, which then exerts continuing downward pressure on price inflation. The markup is also the primary channel through which wages affect prices: the marginal explanatory of lagged wage growth is minimal, given the markup.

The markup model provides a practical and intuitively appealing alternative to time-varying-NAIRU models like Gordon's (1997) and Staiger, Stock and Watson's (1997a,b), which "explain" the persistent errors of the standard Phillips-curve model by assuming that the NAIRU follows a random walk or a complicated time trend. In the random-walk model, if you face a favorable unemployment–inflation trade-off today, your best guess is that you will face an equally favorable trade-off in the future. In the markup model, in contrast, favorable unemployment– inflation trade-offs tend to fade with time: Phillips-curve shifts, while persistent, are temporary. Currently, the markup model suggests that inflation will drift upward absent either a fairly sharp rise in the unemployment rate or a further increase in productivity growth.

Appendix: The Dynamics of the Markup

This appendix provides a simple illustration of how changes in productivity growth are transmitted to the markup and, hence, have a persistent effect on price inflation. The starting point for this exercise are stripped-down versions of Equations 5a,b and 6a,b in which $a(L) = a'(L) = 0$ and $b'(L)$ and $c(L)$ are both of order one, so that

$$\Delta^2 p(t) = c_0 \Delta^2 q(t) + \alpha_1 [u(t-1) - u^*] + \mu_1 [m(t-1) - m^*] + \epsilon(t) \tag{A.1}$$

and

$$\Delta^2 w(t) = b'_1 \Delta m(t-1) + \alpha'_1 [u(t-1) - u^*] + \epsilon'(t). \tag{A.2}$$

I assume that $-1 < \mu_1 < 0$, $0 \leq b'_1 < 1$ and $-1 < c_0 \leq 0$. The first condition says that price inflation moves only part way to close the markup gap over the course of one period; the second condition says that non-negative weight is given to both lagged wage inflation and lagged growth in revenue per worker in the wage equation; and the third condition says that increases in productivity growth have an immediate–but only partial–restraining effect on price inflation. The empirical estimates reported in Tables 1 and 2 suggest that $\mu_1 \approx -0.3$, $b'_1 \approx 0.0$ and $c_0 \approx -0.4$ in the non-financial corporate sector and $\mu_1 \approx -0.2$, $b'_1 \approx 0.4$ and $c_0 \approx -0.3$ in the non-farm business sector.

By adding $\Delta^2 q(t)$ to both sides of A.1, subtracting A.2, and rearranging terms one obtains

$$y(t) = (2 + \mu_1 - b'_1)\, y(t-1) - (1 - b'_1) y(t-2) + (1 + c_0) \Delta^2 q(t) + (\alpha_1 - \alpha'_1)[u(t-1) - u^*] + [\epsilon(t) - \epsilon'(t)], \tag{A.3}$$

where $y(t) \equiv m(t) - m^*$ is the deviation of the markup from its long-run equilibrium value. This is a second-order stochastic difference equation. Its roots are

$$(2 + \mu_1 - b'_1)/2 \pm [(2 + \mu_1 - b'_1)^2 - 4(1 - b'_1)]^{1/2}/2.$$

Both roots are real, non-negative, and stable provided that $\mu_1 + 2(-\mu_1)^{1/2} < b'_1$. The markup rises by $(1 + c_0)$ in immediate response to an increase in productivity growth and remains elevated thereafter, approaching m^* asymptotically. The approach is monotonic if $\mu_1 - b'_1 \leq -1$. Otherwise the impulse response function is hump-shaped. In either case, increases in productivity growth have a persistent effect on the markup and, hence, on price inflation.

If $\mu_1 + 2(-\mu_1)^{1/2} > b'_1$ –as the coefficient estimates reported in Tables 1 and 2 suggest–then the roots of A.3 are complex conjugate. The modulus of the roots is less than 1, so that the markup exhibits damped multi-period oscillations in response to an increase in productivity growth. The markup rises by $(1 + c_0)$ initially. As before, whether the response is subsequently hump-shaped or decreasing is determined by whether $\mu_1 - b'_1 > -1$ or $\mu_1 - b'_1 < -1$. If $\mu_1 \approx -0.2$ and $b'_1 \approx 0.4$, the first inequality applies. Each oscillation is approximately 14 periods (years) in length. The lesson is the same as in the case of real roots: through the markup, increases in productivity growth can have very long-lasting negative effects on price inflation.

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TABLE 1A. Estimated Price Dynamics (Equation 4a)–Non-Financial Corporate Sector
(Standard errors appear in parentheses.)

Variable	**1**	**2**	**2'**	**3**	**4**	**5**
Constant	0.065** (0.020)	0.047** (0.011)	0.046** (0.011)	0.051** (0.010)	0.050** (0.012)	0.052** (0.014)
Nixon Dummy	0.004 (0.005)	—	—	—	---	---
$\Delta^2 p(t - 1)$	-0.445* (0.187)	-0.303* (0.146)	-0.324* (0.146)	-0.342* (0.138)	-0.381* (0.169)	-0.426* (0.195)
$\Delta^2 p(t - 2)$	-0.247 (0.150)	-0.365** (0.118)	-0.373** (0.118)	-0.378** (0.109)	-0.406** (0.128)	-0.393* (0.152)
$\Delta^2 p(t - 3)$	0.053 (0.164)	-0.048 (0.103)	-0.045 (0.103)	-0.064 (0.093)	-0.027 (0.111)	-0.040 (0.130)
$\Delta m(t - 1)$	0.228 (0.292)	---	---	---	---	---
$\Delta m(t - 2)$	0.043 (0.242)	---	---	---	---	---
$\Delta m(t - 3)$	0.490 (0.247)	---	---	---	---	---
$\Delta m(t - 4)$	0.167 (0.242)	---	---	---	---	---
$\Delta^2 q(t)$	-0.505** (0.104)	-0.442** (0.079)	-0.422** (0.078)	-0.422** (0.076)	-0.413** (0.094)	-0.474** (0.111)
$\Delta^2 q(t - 1)$	-0.425* (0.210)	-0.354** (0.128)	-0.337* (0.128)	-0.327** (0.118)	-0.394* (0.157)	-0.393* (0.169)
$\Delta^2 q(t - 2)$	-0.092 (0.183)	-0.210 (0.132)	-0.204 (0.132)	-0.200 (0.122)	-0.298 (0.165)	-0.293 (0.176)
$\Delta^2 q(t - 3)$	0.003 (0.180)	0.063 (0.104)	0.066 (0.104)	0.052 (0.092)	0.023 (0.116)	0.014 (0.132)
$u(t - 1)$	-0.924** (0.273)	-0.690** (0.156)	-0.695** (0.155)	-0.748** (0.150)	-0.740** (0.179)	-0.763** (0.199)
$m(t - 1)$	-0.550* (0.220)	-0.292** (0.106)	-0.252* (0.103)	-0.324** (0.090)	-0.297** (0.103)	-0.329* (0.132)
Adj. R^2	0.560	0.592	0.591	0.595	0.565	0.602
Stnd. Error	0.0119	0.0115	0.0115	0.0114	0.0136	0.0113

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 1B. Estimated Wage Dynamics (Equation 4b)–Non-Financial Corporate Sector
(Standard errors appear in parentheses.)

Variable	**1**	**2**	**2'**	**3**	**4**	**5**
Constant	0.073^{**} (0.017)	0.054^{**} (0.012)	0.036^{**} (0.007)	0.035^{**} (0.007)	0.029^{**} (0.008)	0.033^{**} (0.008)
Nixon Dummy	-0.001 (0.004)	—	—	—	—	—
$\Delta^2 w(t-1)$	-0.586^{**} (0.157)	-0.380^{**} (0.123)	-0.335^{*} (0.126)	-0.327^{**} (0.106)	-0.287^{*} (0.129)	-0.274 (0.135)
$\Delta^2 w(t-2)$	-0.051 (0.135)	-0.083 (0.111)	-0.098 (0.115)	-0.149 (0.100)	-0.049 (0.126)	-0.098 (0.124)
$\Delta^2 w(t-3)$	-0.327^{*} (0.139)	-0.335^{**} (0.116)	-0.401^{**} (0.115)	-0.492^{**} (0.095)	-0.504^{**} (0.117)	-0.528^{**} (0.119)
$\Delta m(t-1)$	0.172 (0.231)	0.323 (0.166)	0.103 (0.119)	---	---	---
$\Delta m(t-2)$	0.738^{**} (0.269)	0.324^{*} (0.153)	0.129 (0.114)	---	---	---
$\Delta m(t-3)$	0.447 (0.252)	0.284^{*} (0.133)	0.139 (0.111)	---	---	---
$\Delta m(t-4)$	0.184 (0.146)	0.125 (0.104)	0.048 (0.099)	---	---	---
$\Delta^2 q(t)$	-0.032 (0.090)	—	—	---	---	---
$\Delta^2 q(t-1)$	0.250 (0.167)	---	---	---	---	---
$\Delta^2 q(t-2)$	-0.077 (0.126)	---	---	---	---	---
$\Delta^2 q(t-3)$	-0.060 (0.139)	---	---	---	---	---
$u(t-1)$	-1.070^{**} (0.232)	-0.821^{**} (0.162)	-0.600^{**} (0.111)	-0.574^{**} (0.113)	-0.477^{**} (0.123)	-0.537^{**} (0.127)
$m(t-1)$	-0.459^{*} (0.188)	-0.257 (0.142)	—	---	---	---
Adj. R^2	0.465	0.505	0.481	0.514	0.480	0.520
Stnd. Error	0.0104	0.0100	0.0102	0.0099	0.0100	0.0098

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 2A. Estimated Price Dynamics (Equation 4a)–Non-Farm Business Sector
(Standard errors appear in parentheses.)

Variable	**1**	**2**	**3**	**4**	**5**
Constant	1.269* (0.512)	0.977* (0.369)	1.007** (0.325)	1.305* (0.490)	1.018* (0.433)
Nixon Dummy	-0.014** (0.004)	-0.017** (0.003)	-0.018** (0.003)	-0.017** (0.004)	-0.018** (0.004)
$\Delta^2 p(t-1)$	-0.309* (0.145)	-0.394** (0.108)	-0.335** (0.091)	-0.327** (0.096)	-0.357** (0.117)
$\Delta^2 p(t-2)$	-0.144 (0.125)	-0.301** (0.100)	-0.298** (0.075)	-0.289** (0.079)	-0.287** (0.095)
$\Delta^2 p(t-3)$	-0.176 (0.118)	-0.124 (0.091)	-0.189* (0.076)	-0.206* (0.078)	-0.180 (0.098)
$\Delta m(t-1)$	-0.097 (0.168)	---	---	---	---
$\Delta m(t-2)$	0.048 (0.163)	---	---	---	---
$\Delta m(t-3)$	0.351* (0.171)	---	---	---	---
$\Delta m(t-4)$	-0.022 (0.174)	---	---	---	---
$\Delta^2 q(t)$	-0.369** (0.086)	-0.328** (0.074)	-0.288** (0.058)	-0.270** (0.069)	-0.281** (0.074)
$\Delta^2 q(t-1)$	-0.004 (0.168)	-0.112 (0.117)	---	---	---
$\Delta^2 q(t-2)$	0.077 (0.162)	-0.074 (0.115)	---	---	---
$\Delta^2 q(t-3)$	-0.055 (0.144)	0.033 (0.086)	---	---	---
$u(t-1)$	-0.581** (0.133)	-0.668** (0.115)	-0.681** (0.116)	-0.689** (0.134)	-0.691** (0.134)
$m(t-1)$	-0.269* (0.111)	-0.204* (0.080)	-0.224** (0.070)	-0.275* (0.107)	-0.212* (0.094)
Adjusted R^2	0.657	0.668	0.681	0.668	0.682
Stnd. Error	0.0108	0.0106	0.0104	0.0120	0.0104

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 2B. Estimated Wage Dynamics (Equation 4b)–Non-Farm Business Sector
(Standard errors appear in parentheses.)

Variable	1	2	3	4	5
Constant	0.206 (0.511)	0.060 (0.460)	0.037** (0.007)	0.034** (0.007)	0.034** (0.008)
Nixon Dummy	-0.004 (0.004)	-0.005 (0.003)	-0.005 (0.003)	-0.005 (0.003)	-0.004 (0.004)
$\Delta^2 w(t-1)$	-0.236 (0.145)	-0.257* (0.120)	-0.248* (0.109)	-0.270* (0.116)	-0.198 (0.139)
$\Delta^2 w(t-2)$	0.067 (0.125)	-0.024 (0.108)	-0.071 (0.095)	0.028 (0.103)	-0.019 (0.118)
$\Delta^2 w(t-3)$	-0.448** (0.118)	-0.412** (0.103)	-0.490** (0.087)	-0.527** (0.091)	-0.537** (0.109)
$\Delta m(t-1)$	0.288 (0.157)	0.313** (0.113)	0.306** (0.094)	0.277** (0.085)	0.277* (0.114)
$\Delta m(t-2)$	0.220 (0.186)	0.102 (0.119)	---	---	---
$\Delta m(t-3)$	0.129 (0.173)	0.096 (0.111)	---	---	---
$\Delta m(t-4)$	-0.060 (0.137)	-0.073 (0.099)	---	---	---
$\Delta^2 q(t)$	-0.034 (0.086)	---	---	---	---
$\Delta^2 q(t-1)$	0.006 (0.126)	---	---	---	---
$\Delta^2 q(t-2)$	-0.064 (0.119)	---	---	---	---
$\Delta^2 q(t-3)$	-0.025 (0.113)	---	---	---	---
$u(t-1)$	-0.583** (0.132)	-0.624** (0.114)	-0.622** (0.112)	-0.567** (0.114)	-0.577** (0.129)
$m(t-1)$	-0.037 (0.111)	-0.005 (0.100)	---	---	---
Adjusted R^2	0.506	0.558	0.577	0.561	0.585
Stnd. Error	0.0108	0.0102	0.0100	0.0099	0.0099

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 3. Significance Levels for Tests of Serial Correlation (4 lags)

	Ljung-Box Q Statistic	**Breusch-Godfrey F**	**Breusch-Godfrey nR^2**
Non-Financial Corp.			
Price Equation 5a	0.690	0.309	0.152
Wage Equation 5b	0.809	0.987	0.984
Non-Farm Business			
Price Equation 6a	0.822	0.668	0.535
Wage Equation 6b	0.844	0.704	0.593

TABLE 4A. Robustness of Estimated Price Dynamics–Non-Financial Corporate Sector (Equation 5a)

(Standard errors appear in parentheses.)

Variable	Baseline	Duration	Male U.	Oil Price	PCE Price	Inst. Var.
Constant	0.051^{**} (0.010)	0.050^{**} (0.107)	0.044^{**} (0.011)	0.048^{**} (0.010)	0.051^{**} (0.010)	0.049^{**} (0.014)
$\Delta^2 p(t - 1)$	-0.342^{*} (0.138)	-0.354^{*} (0.138)	-0.357^{*} (0.138)	-0.342^{*} (0.138)	-0.354^{*} (0.142)	-0.613^{**} (0.213)
$\Delta^2 p(t - 2)$	-0.378^{**} (0.109)	-0.369^{**} (0.111)	-0.386^{**} (0.110)	-0.371^{**} (0.108)	-0.359^{**} (0.114)	-0.400^{*} (0.151)
$\Delta^2 p(t - 3)$	-0.064 (0.093)	-0.054 (0.096)	-0.074 (0.093)	-0.071 (0.093)	-0.047 (0.097)	-0.010 (0.130)
$\Delta^2 q(t)$	-0.422^{**} (0.076)	-0.433^{**} (0.077)	-0.428^{**} (0.077)	-0.411^{**} (0.079)	-0.423^{**} (0.078)	-0.815^{**} (0.197)
$\Delta^2 q(t - 1)$	-0.327^{**} (0.118)	-0.347^{**} (0.119)	-0.339^{**} (0.117)	-0.299^{*} (0.124)	-0.349^{**} (0.128)	-0.711^{**} (0.227)
$\Delta^2 q(t - 2)$	-0.200 (0.122)	-0.218 (0.123)	-0.211 (0.122)	-0.185 (0.125)	-0.173 (0.133)	-0.585^{*} (0.224)
$\Delta^2 q(t - 3)$	0.052 (0.092)	0.043 (0.091)	0.047 (0.092)	0.067 (0.094)	0.078 (0.103)	0.124 (0.147)
$u(t - 1)$	-0.748^{**} (0.150)	-0.795^{**} (0.192)	-0.373 (0.314)	-0.714^{**} (0.147)	-0.749^{**} (0.152)	-0.694^{**} (0.200)
$m(t - 1)$	-0.324^{**} (0.090)	-0.357^{**} (0.102)	-0.321^{**} (0.091)	-0.315^{**} (0.091)	-0.328^{**} (0.095)	-0.373^{**} (0.133)
$dur(t - 1)$	—	0.028 (0.086)	—	—	—	—
$mu(t - 1)$	—	—	-0.379 (0.286)	—	—	—
$\Delta o(t)$	—	—	—	0.015 (0.008)	—	—
Adj. R^2	0.595	0.581	0.600	0.615	0.589	0.464
Stnd. Error	0.0114	0.0116	0.0113	0.0111	0.0115	0.0131

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 4B. Robustness of Estimated Wage Dynamics–Non-Financial Corporate Sector (Equation 5b)

(Standard errors appear in parentheses.)

Variable	**Baseline**	**Duration**	**Male U.**	**Oil Price**	**PCE Price**
Constant	0.035** (0.007)	0.038** (0.009)	0.026** (0.008)	0.032** (0.007)	0.034** (0.007)
$\Delta^2 w(t-1)$	-0.327** (0.106)	-0.346** (0.107)	-0.356** (0.101)	-0.324** (0.103)	-0.331* (0.128)
$\Delta^2 w(t-2)$	-0.149 (0.100)	-0.175 (0.106)	-0.179 (0.096)	-0.132 (0.098)	-0.105 (0.123)
$\Delta^2 w(t-3)$	-0.492** (0.095)	-0.506** (0.097)	-0.517** (0.090)	-0.505** (0.093)	-0.472** (0.117)
$u(t-1)$	-0.574** (0.113)	-0.536** (0.133)	0.013 (0.260)	-0.525** (0.110)	-0.558** (0.113)
$dur(t-1)$	—	-0.041 (0.069)	—	—	—
$mu(t-1)$	—	—	-0.610* (0.249)	—	—
$\Delta o(t)$	—	—	—	0.015* (0.007)	—
$\Delta m'(t-1)$	—	—	—	—	-0.043 (0.108)
$\Delta m'(t-2)$	—	—	—	—	0.073 (0.096)
$\Delta m'(t-3)$	—	—	—	—	0.012 (0.094)
$\Delta m'(t-4)$	—	—	—	—	-0.058 (0.094)
Adj. R^2	0.514	0.501	0.567	0.553	0.453
Stnd. Error	0.0099	0.0100	0.0093	0.0095	0.0105

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 5A. Robustness of Estimated Price Dynamics–Non-Farm Business Sector (Equation 6a)

(Standard errors appear in parentheses.)

Variable	**Baseline**	**Duration**	**Male U.**	**Oil Price**	**PCE Price**	**Inst. Var.**
Constant	1.007** (0.325)	1.361** (0.466)	1.053** (0.349)	0.855** (0.291)	1.106** (0.350)	1.131* (0.449)
Nixon Dummy	-0.018** (0.003)	-0.017** (0.003)	-0.018** (0.003)	-0.016** (0.003)	-0.018** (0.003)	-0.018** (0.004)
$\Delta^2 p(t-1)$	-0.335** (0.091)	-0.304** (0.098)	-0.355** (0.094)	-0.331** (0.080)	-0.329** (0.093)	-0.337** (0.120)
$\Delta^2 p(t-2)$	-0.298** (0.075)	-0.282** (0.080)	-0.316** (0.076)	-0.320** (0.067)	-0.280** (0.077)	-0.268** (0.097)
$\Delta^2 p(t-3)$	-0.189* (0.076)	-0.176* (0.081)	-0.203* (0.077)	-0.197** (0.067)	-0.184* (0.078)	-0.193 (0.100)
$\Delta^2 q(t)$	-0.288** (0.058)	-0.305** (0.060)	-0.279** (0.060)	-0.242** (0.053)	-0.285** (0.061)	-0.350** (0.097)
$u(t-1)$	-0.681** (0.116)	-0.718** (0.169)	-0.263 (0.292)	-0.608** (0.104)	-0.679** (0.116)	-0.673** (0.137)
$m(t-1)$	-0.224** (0.070)	-0.288** (0.102)	-0.222** (0.075)	-0.178** (0.063)	-0.232** (0.076)	-0.237* (0.097)
$dur(t-1)$	—	0.032 (0.099)	—	—	—	—
$mu(t-1)$	—	—	-0.434 (0.281)	—	—	—
$\Delta o(t)$	—	—	—	0.024** (0.007)	—	—
Adj. R^2	0.681	0.663	0.693	0.745	0.681	0.673
Stnd. Error	0.0104	0.0107	0.0102	0.0093	0.0104	0.0105

* Significant at the 5% level. ** Significant at the 1% level.

TABLE 5B. Robustness of Estimated Wage Dynamics–Non-Farm Business Sector (Equation 6b)
(Standard errors appear in parentheses.)

Variable	**Baseline**	**Duration**	**Male U.**	**Oil Price**	**PCE Price**
Constant	0.037^{**} (0.007)	0.045^{**} (0.009)	0.028^{**} (0.007)	0.037^{**} (0.007)	0.039^{**} (0.007)
Nixon Dummy	-0.005 (0.003)	-0.006 (0.003)	-0.005 (0.003)	-0.005 (0.003)	-0.008^{*} (0.003)
$\Delta^2 w(t-1)$	-0.248^{*} (0.109)	-0.261^{*} (0.108)	-0.289^{**} (0.103)	-0.268^{*} (0.108)	-0.176 (0.118)
$\Delta^2 w(t-2)$	-0.071 (0.095)	-0.117 (0.099)	-0.119 (0.091)	-0.088 (0.094)	-0.062 (0.110)
$\Delta^2 w(t-3)$	-0.490^{**} (0.087)	-0.517^{**} (0.088)	-0.528^{**} (0.082)	-0.499^{**} (0.086)	-0.488^{**} (0.105)
$\Delta m(t-1)$	0.306^{**} (0.094)	0.350^{**} (0.097)	0.282^{**} (0.087)	0.296^{**} (0.093)	0.627^{**} (0.219)
$u(t-1)$	-0.622^{**} (0.112)	-0.526^{**} (0.129)	0.086 (0.245)	-0.614^{**} (0.114)	-0.626^{**} (0.109)
$dur(t-1)$	—	-0.099 (0.068)	—	—	—
$mu(t-1)$	—	—	-0.737^{**} (0.235)	—	—
$\Delta o(t)$	—	—	—	0.007 (0.008)	—
$\Delta m'(t-1)$	—	—	—	—	-0.297 (0.210)
$\Delta m'(t-2)$	—	—	—	—	0.006 (0.092)
$\Delta m'(t-3)$	—	—	—	—	0.000 (0.088)
$\Delta m'(t-4)$	—	—	—	—	-0.158^{*} (0.079)
Adj. R^2	0.577	0.580	0.650	0.571	0.537
Stnd. Error	0.0100	0.0099	0.0091	0.0100	0.0104

* Significant at the 5% level. ** Significant at the 1% level.

FIGURE 1A. Recursive Residuals from the Price-Inflation Equation (Non-Financial Corporate Sector)

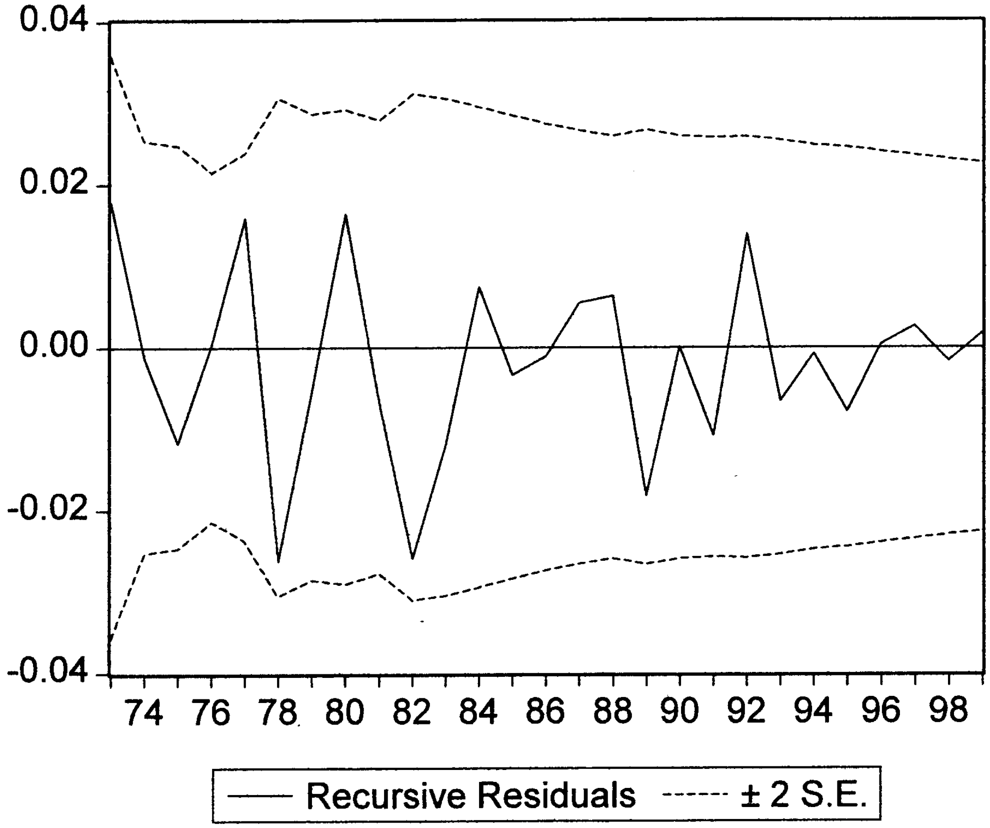


FIGURE 1B. Recursive Residuals from the Wage-Inflation Equation (Non-Financial Corporate Sector)

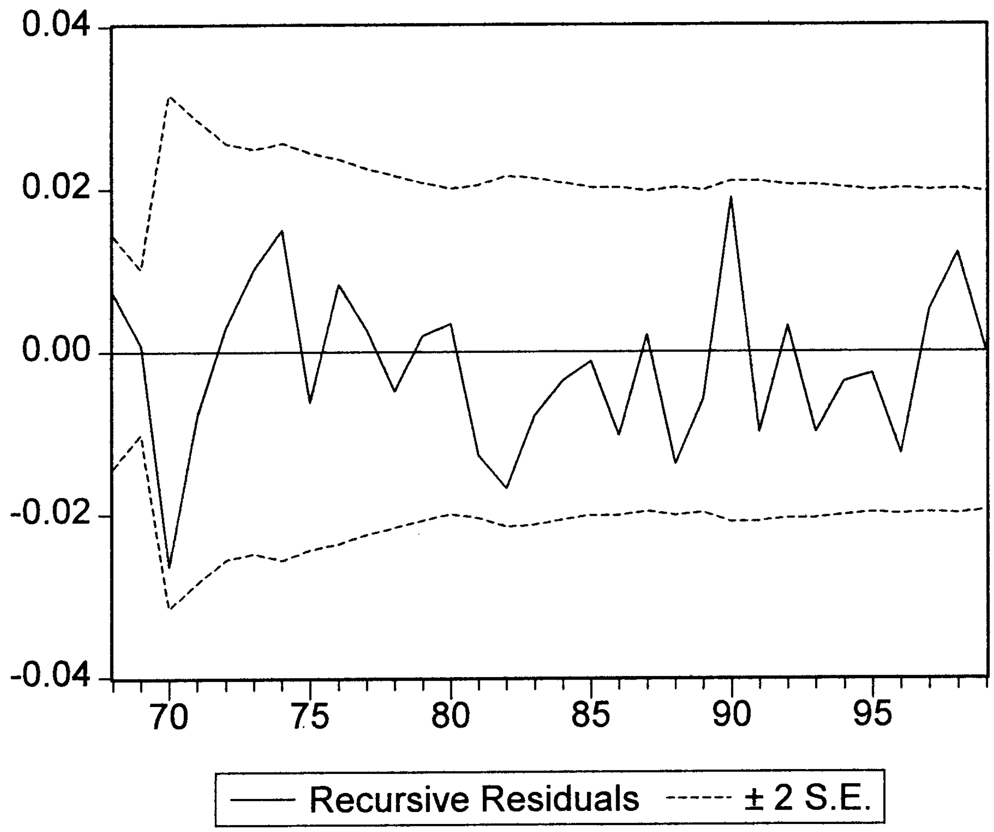


FIGURE 2A. Recursive Residuals from the Price-Inflation Equation (Non-Farm Business Sector)

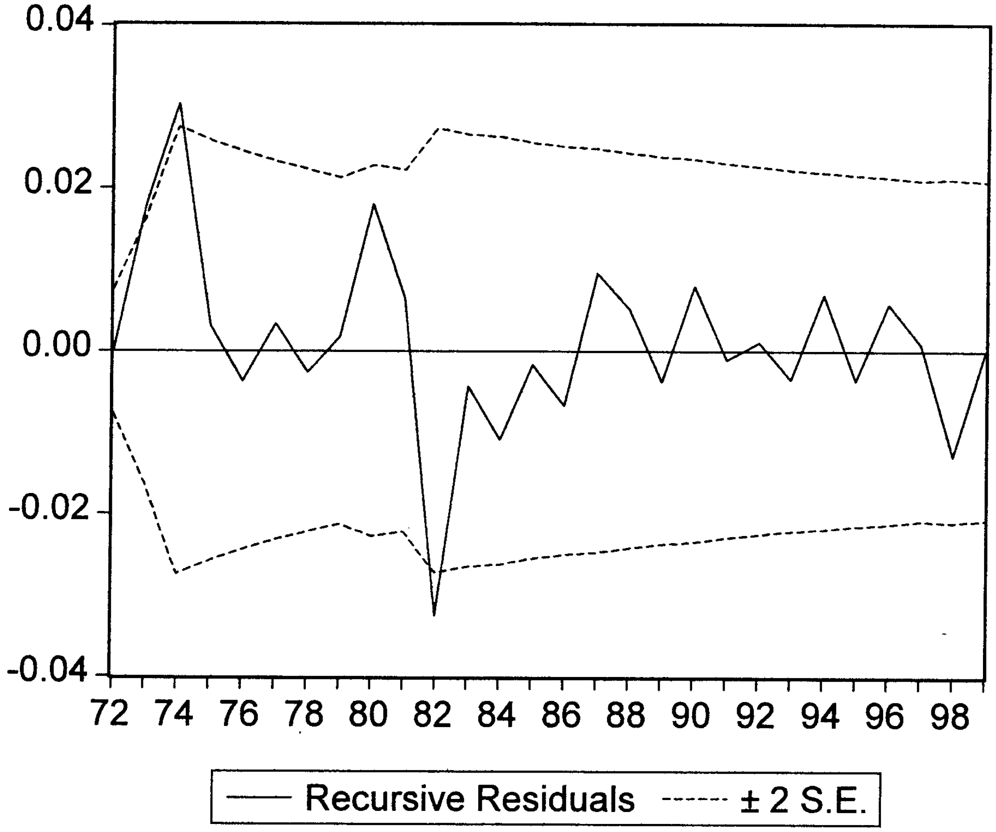


FIGURE 2B. Recursive Residuals from the Wage-Inflation Equation (Non-Farm Business Sector)

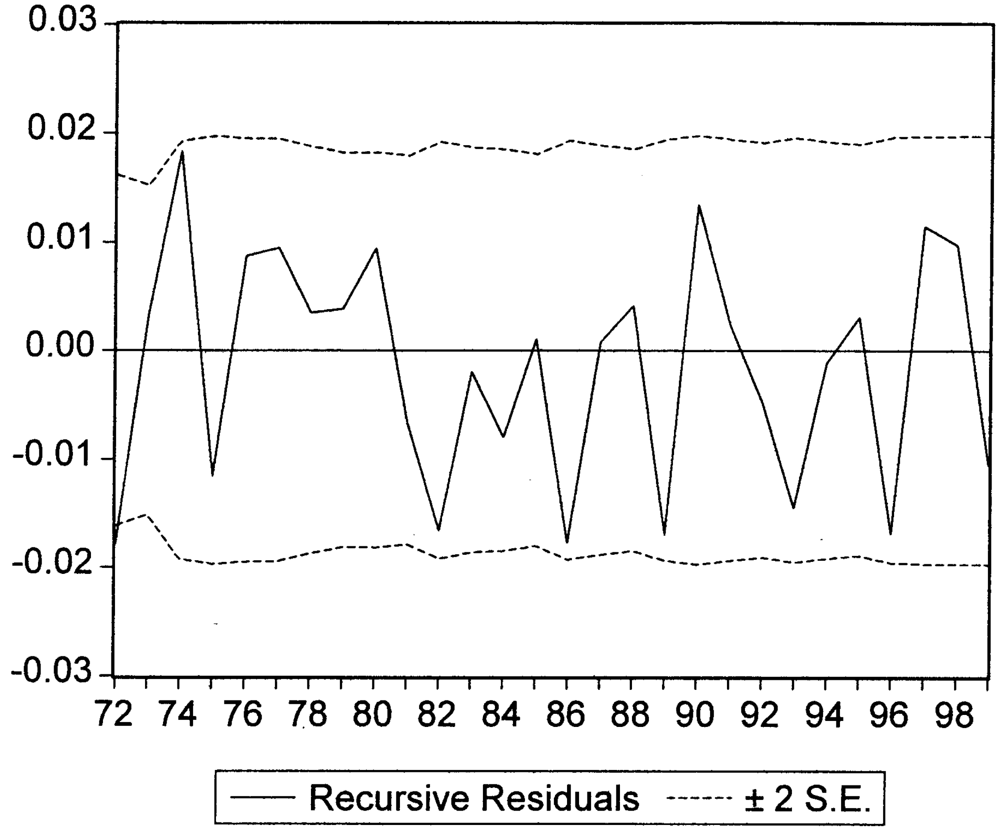


FIGURE 3A. Cumulative Sum of Recursive Residuals from the Price-Inflation Equation (Non-Financial Corporate Sector)

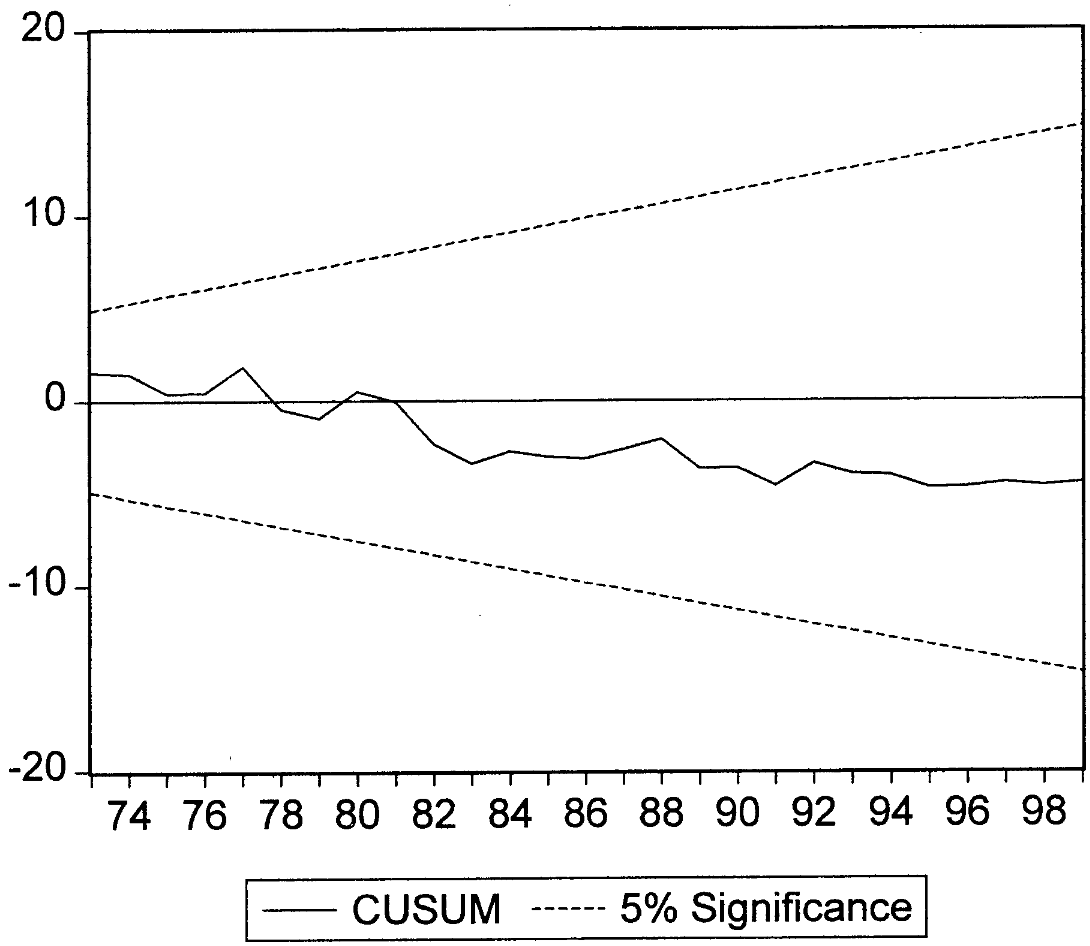


FIGURE 3B. Cumulative Sum of Recursive Residuals from the Wage-Inflation Equation (Non-Financial Corporate Sector)

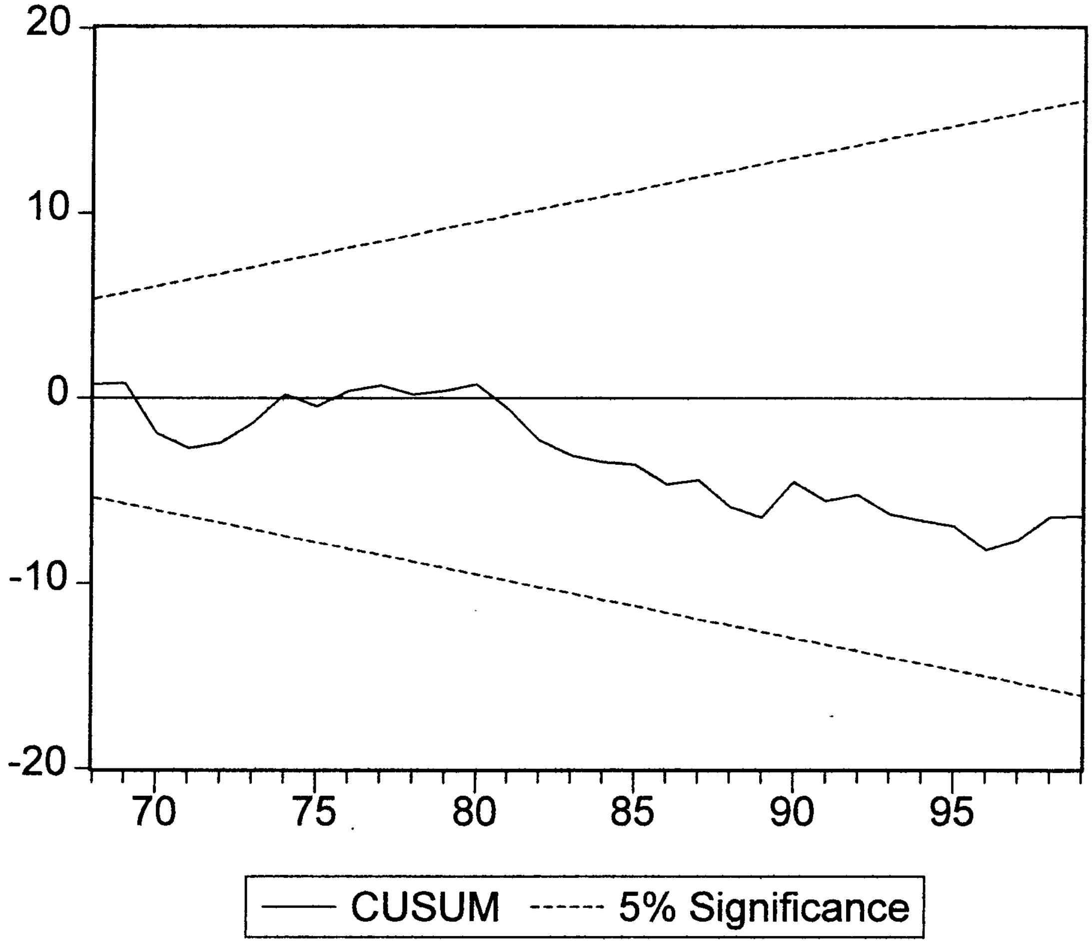


FIGURE 4A. Cumulative Sum of Recursive Residuals from the Price-Inflation Equation
(Non-Farm Business Sector)

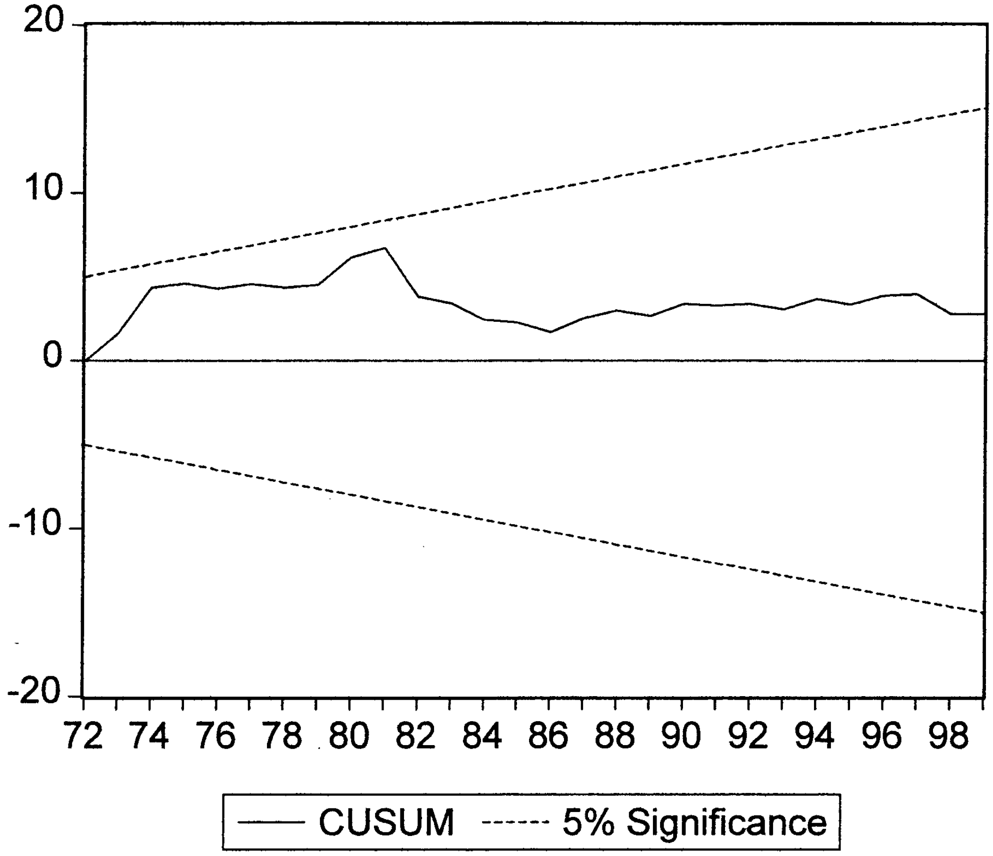


FIGURE 4B. Cumulative Sum of Recursive Residuals from the Wage-Inflation Equation (Non-Farm Business Sector)

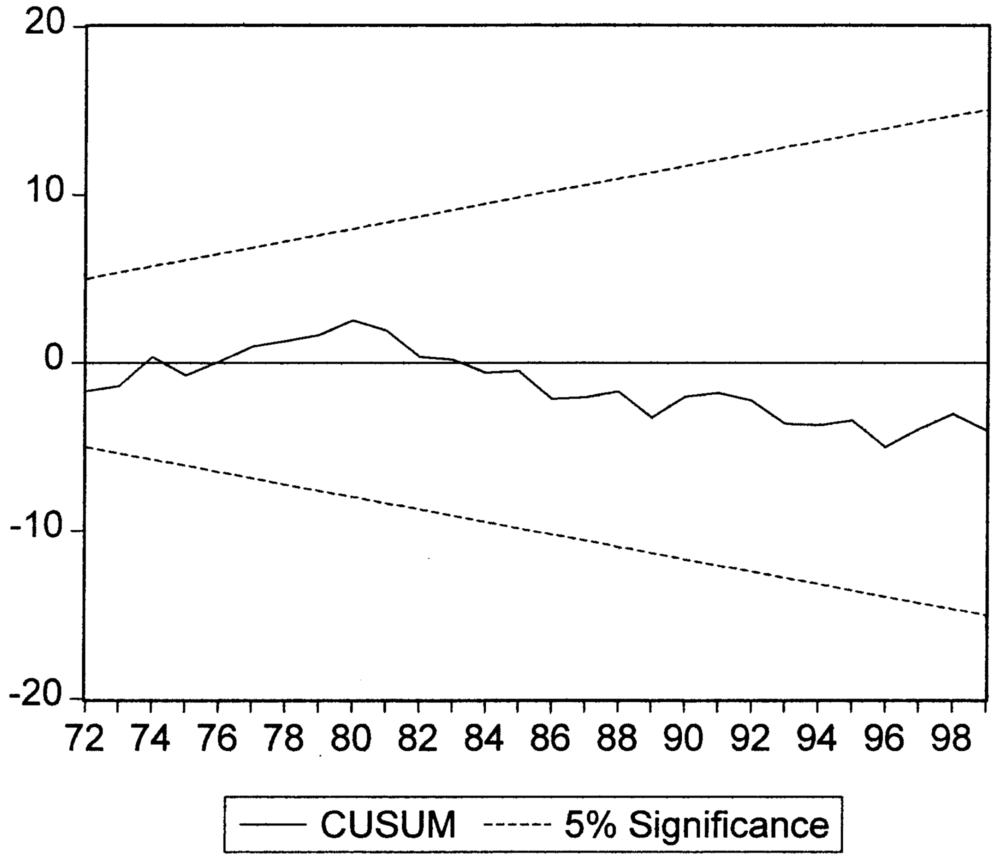
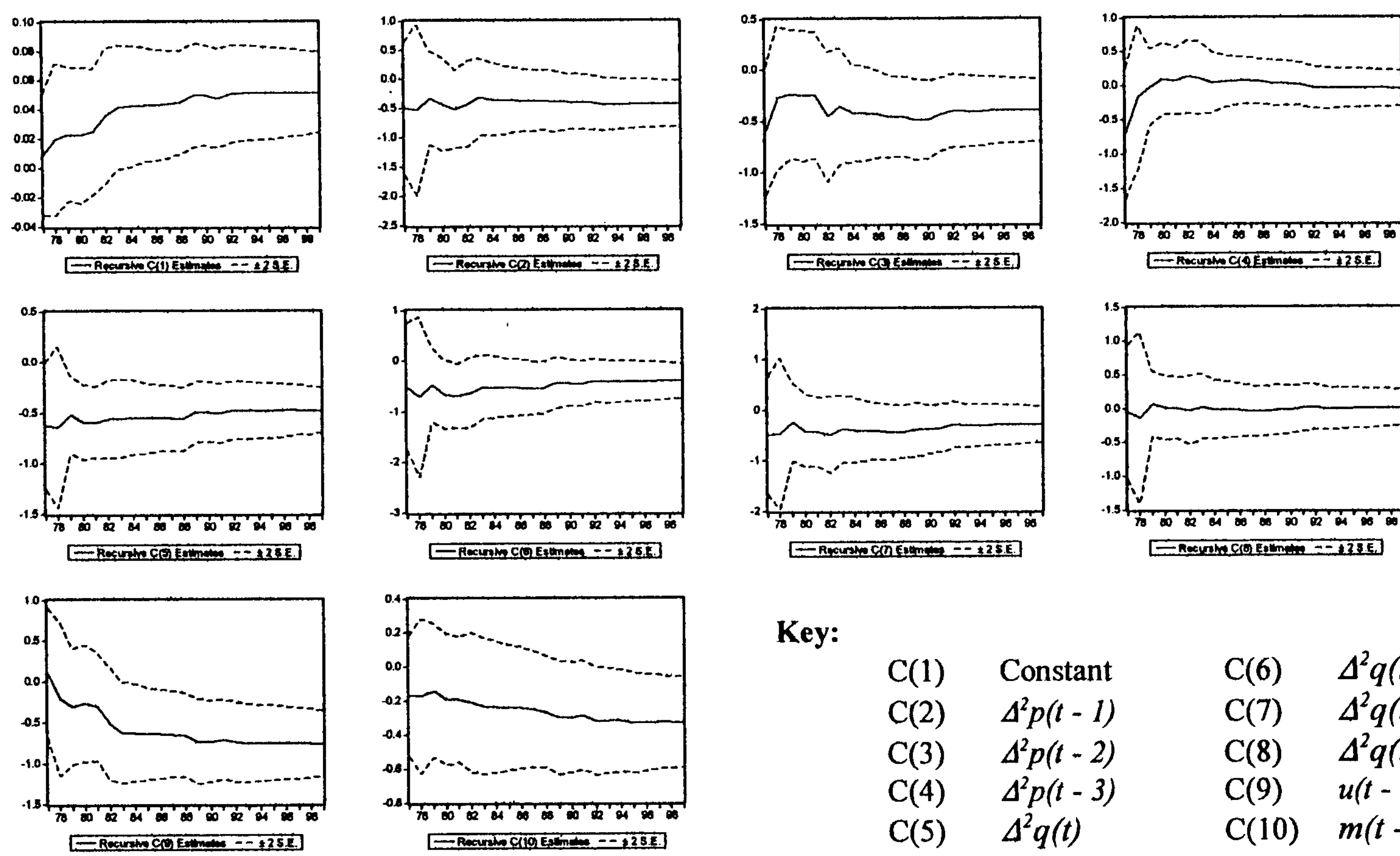


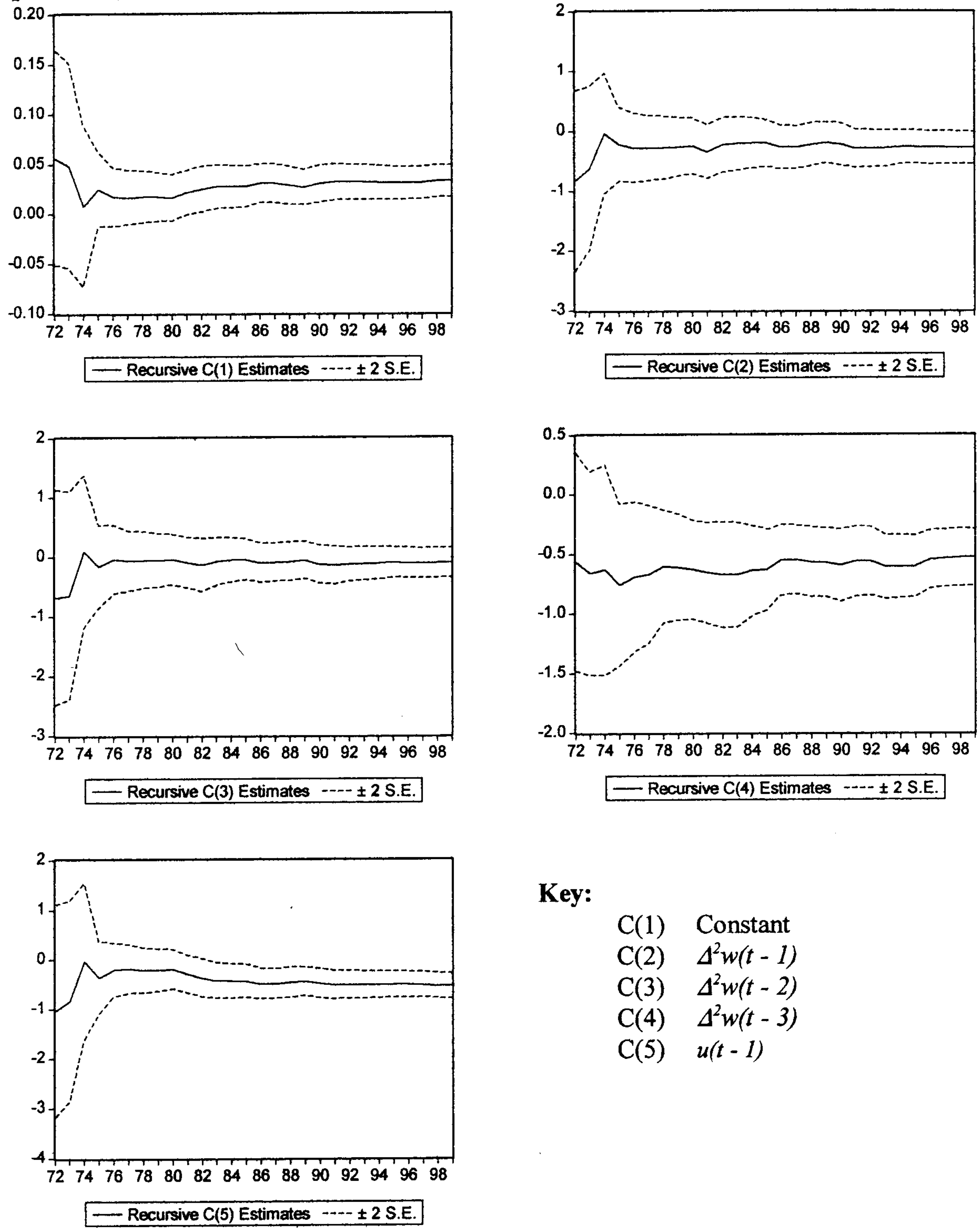
FIGURE 5A. Recursive Coefficient Estimates from the Price-Inflation Equation (Non-Financial Corporate Sector)



Key:

C(1)	Constant	C(6)	$\Delta^2 q(t-1)$
C(2)	$\Delta^2 p(t-1)$	C(7)	$\Delta^2 q(t-2)$
C(3)	$\Delta^2 p(t-2)$	C(8)	$\Delta^2 q(t-3)$
C(4)	$\Delta^2 p(t-3)$	C(9)	$u(t-1)$
C(5)	$\Delta^2 q(t)$	C(10)	$m(t-1)$

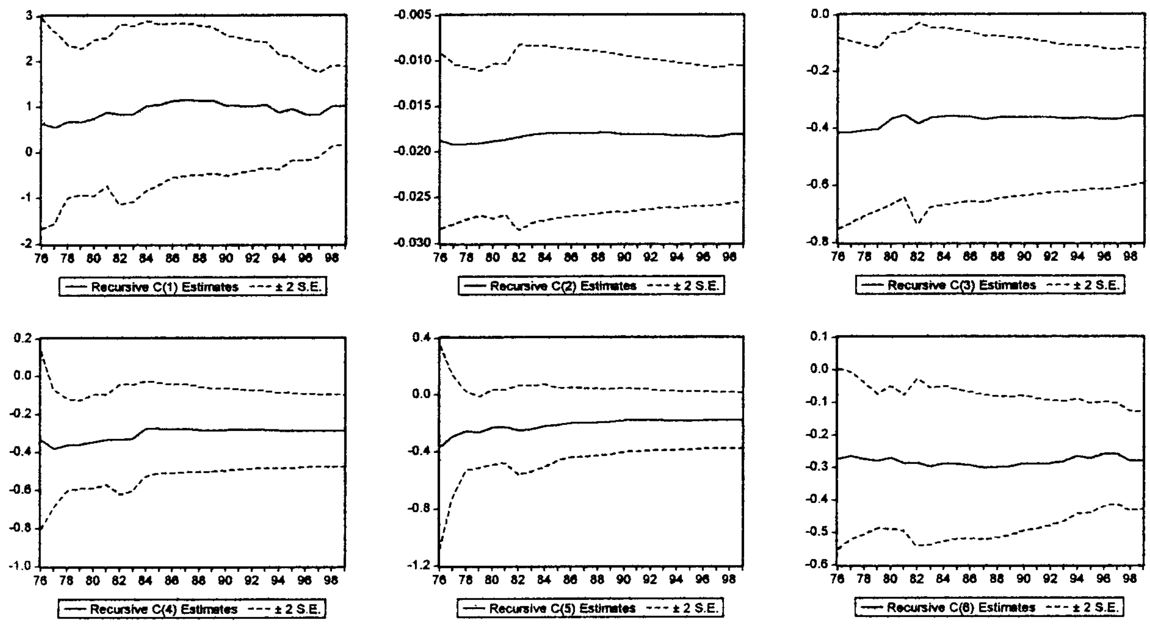
FIGURE 5B. Recursive Coefficient Estimates from the Wage-Inflation Equation (Non-Financial Corporate Sector)

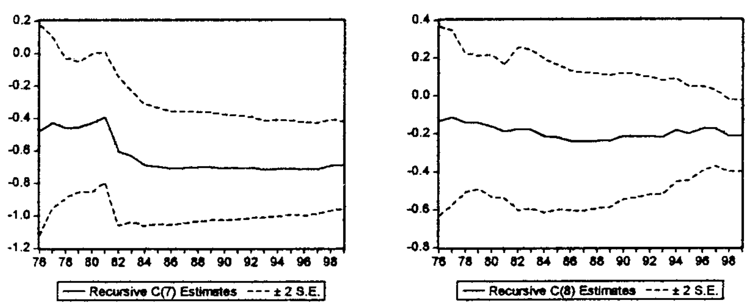


Key:

C(1) Constant
C(2) $\Delta^2 w(t-1)$
C(3) $\Delta^2 w(t-2)$
C(4) $\Delta^2 w(t-3)$
C(5) $u(t-1)$

FIGURE 6A. Recursive Coefficient Estimates from the Price-Inflation Equation (Non-Farm Business Sector)

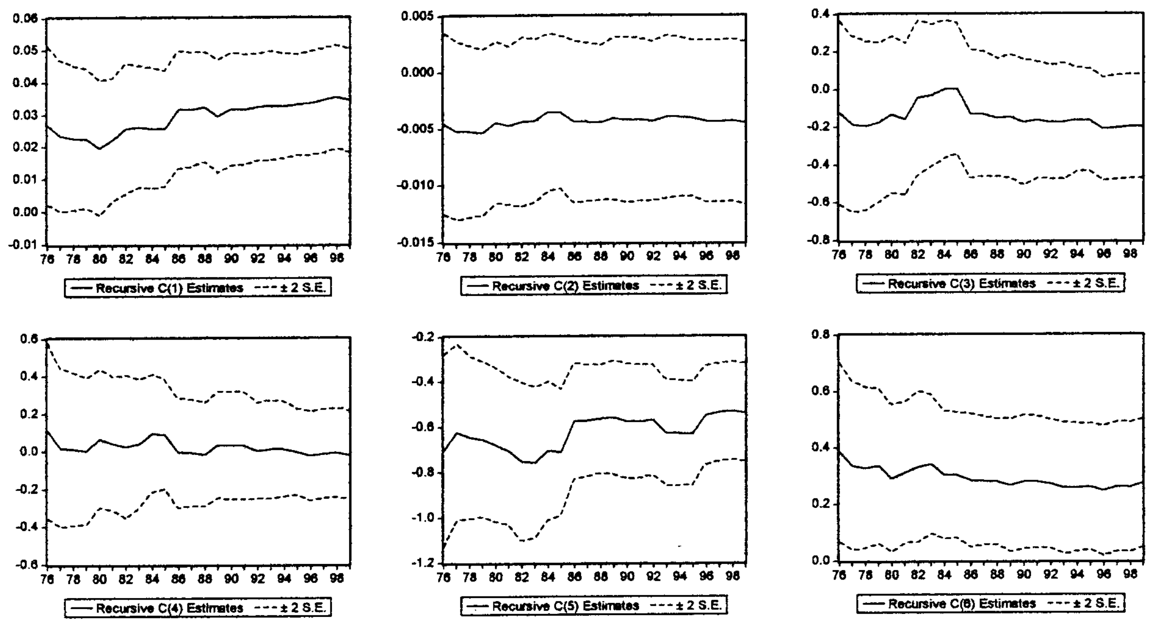


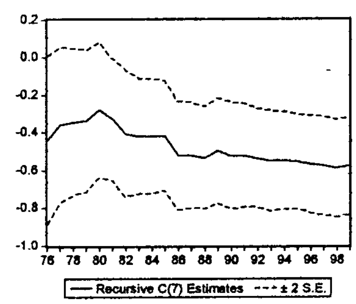


Key:

C(1)	Constant
C(2)	Nixon Dummy
C(3)	$\Delta^2 p(t - 1)$
C(4)	$\Delta^2 p(t - 2)$
C(5)	$\Delta^2 p(t - 3)$
C(6)	$\Delta^2 q(t)$
C(7)	$u(t - 1)$
C(8)	$m(t - 1)$

FIGURE 6B. Recursive Coefficient Estimates from the Wage-Inflation Equation (Non-Farm Business Sector)





Key:

C(1)	Constant
C(2)	Nixon Dummy
C(3)	$\Delta^2 w(t-1)$
C(4)	$\Delta^2 w(t-2)$
C(5)	$\Delta^2 w(t-3)$
C(6)	$\Delta m(t-1)$
C(7)	$u(t-1)$

FIGURE 7. Oil-Price Shocks in the Non-Financial-Corporate and Non-Farm-Business Sectors

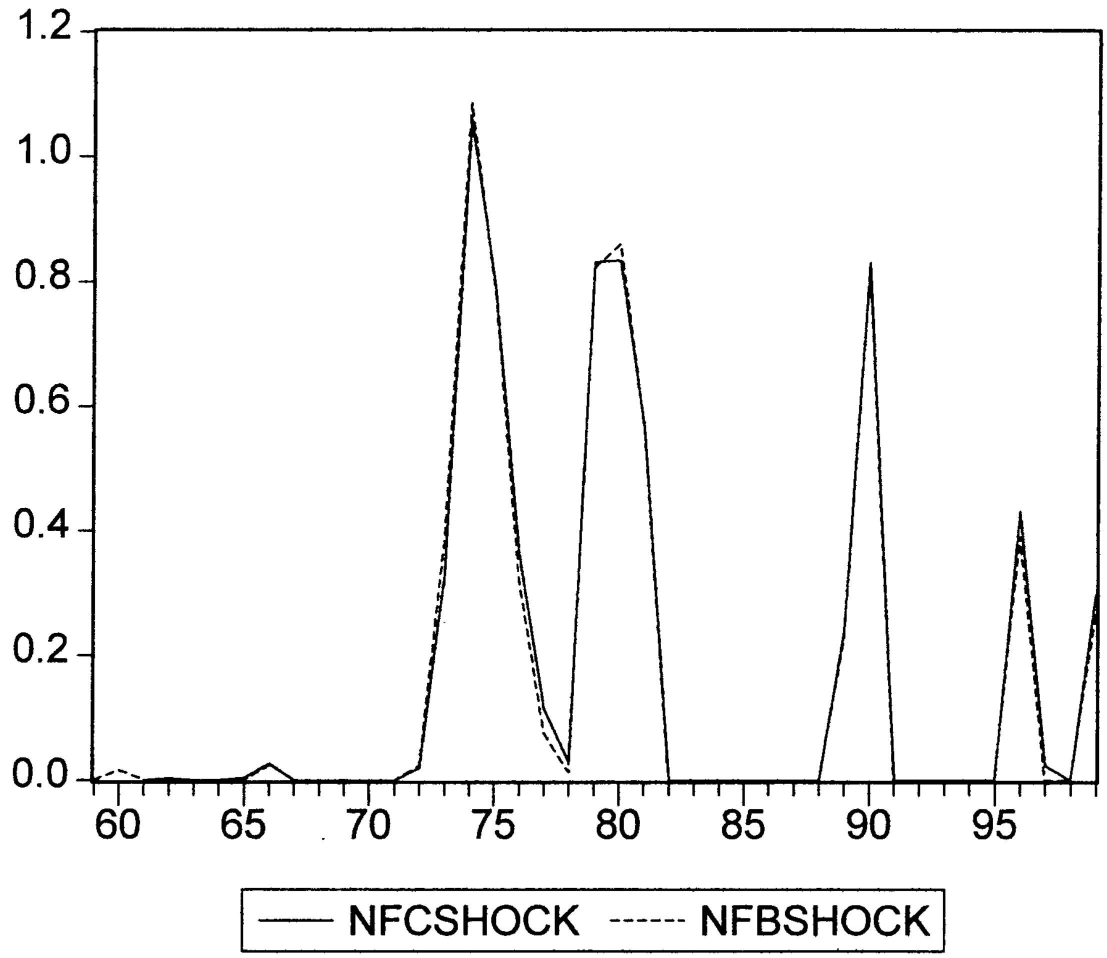


FIGURE 8A. Actual Price Inflation Compared with Simulated Price Inflation from the Conventional-Phillips-Curve and Markup Models (Non-Financial Corporate Sector)

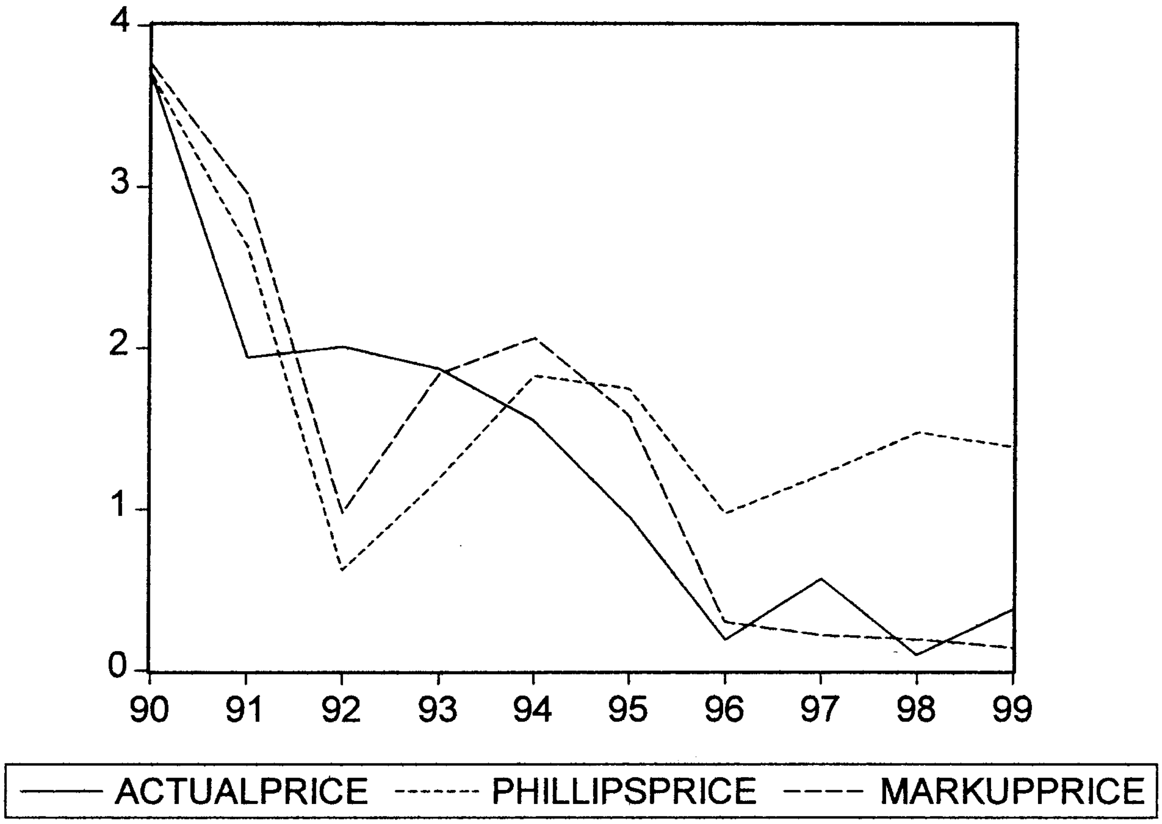


FIGURE 8B. Actual Wage Inflation Compared with Simulated Wage Inflation from the Conventional-Phillips-Curve and Markup Models (Non-Financial Corporate Sector)

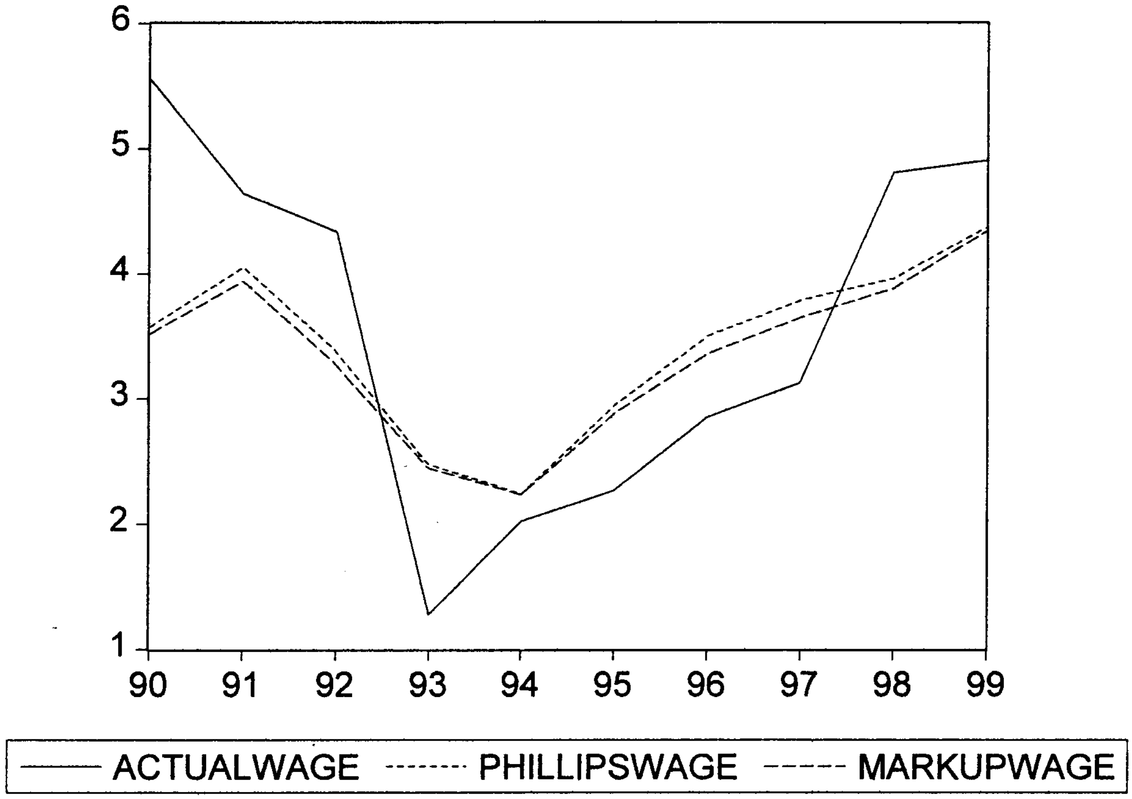


FIGURE 9A. Actual Price Inflation Compared with Simulated Price Inflation from the Conventional-Phillips-Curve and Markup Models (Non-Farm Business Sector)

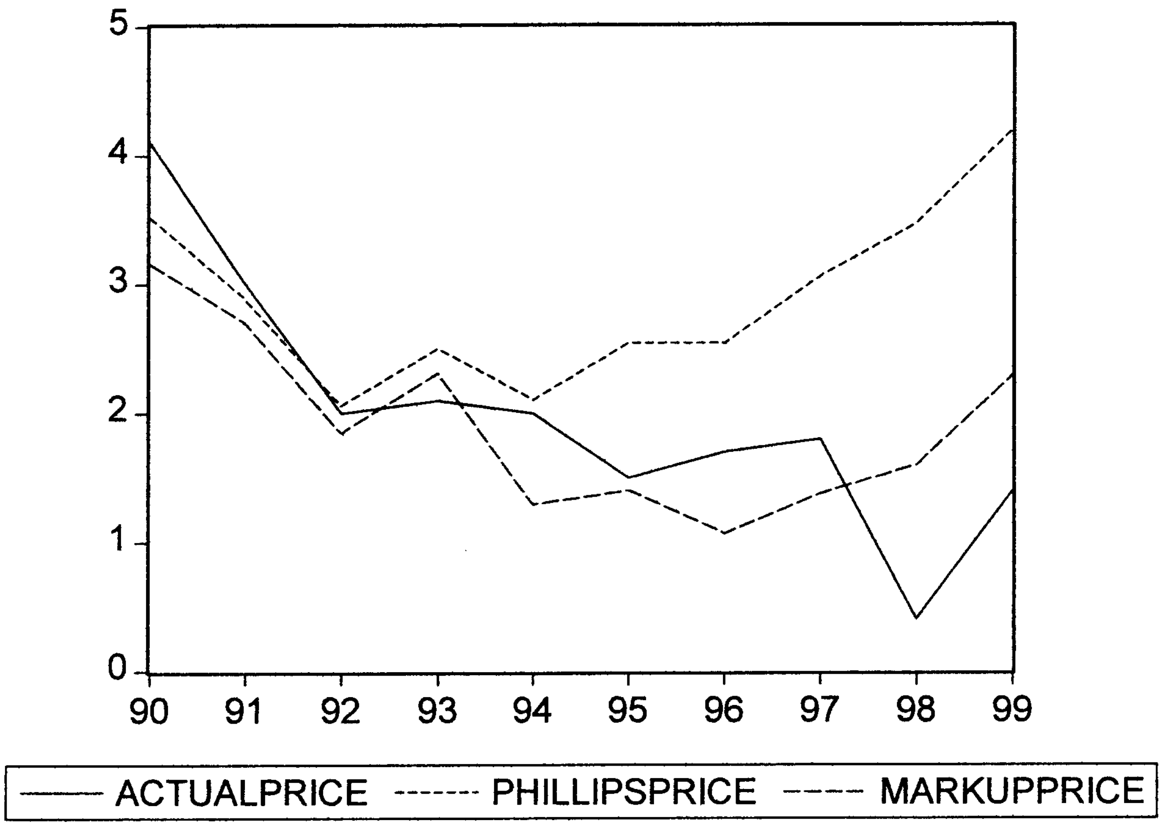


FIGURE 9B. Actual Wage Inflation Compared with Simulated Wage Inflation from the Conventional-Phillips-Curve and Markup Models (Non-Farm Business Sector)

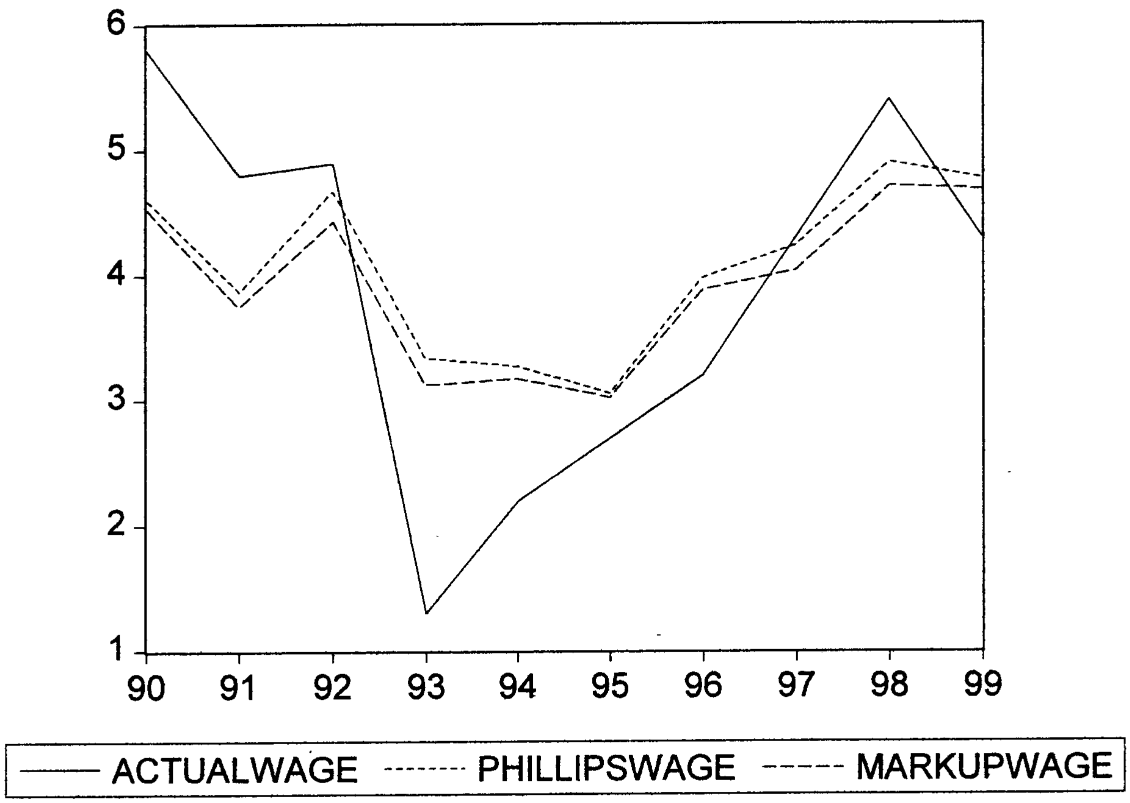


FIGURE 10. The Markup TV-NAIRU and the Unemployment Rate (Non-Financial Corporate Sector)

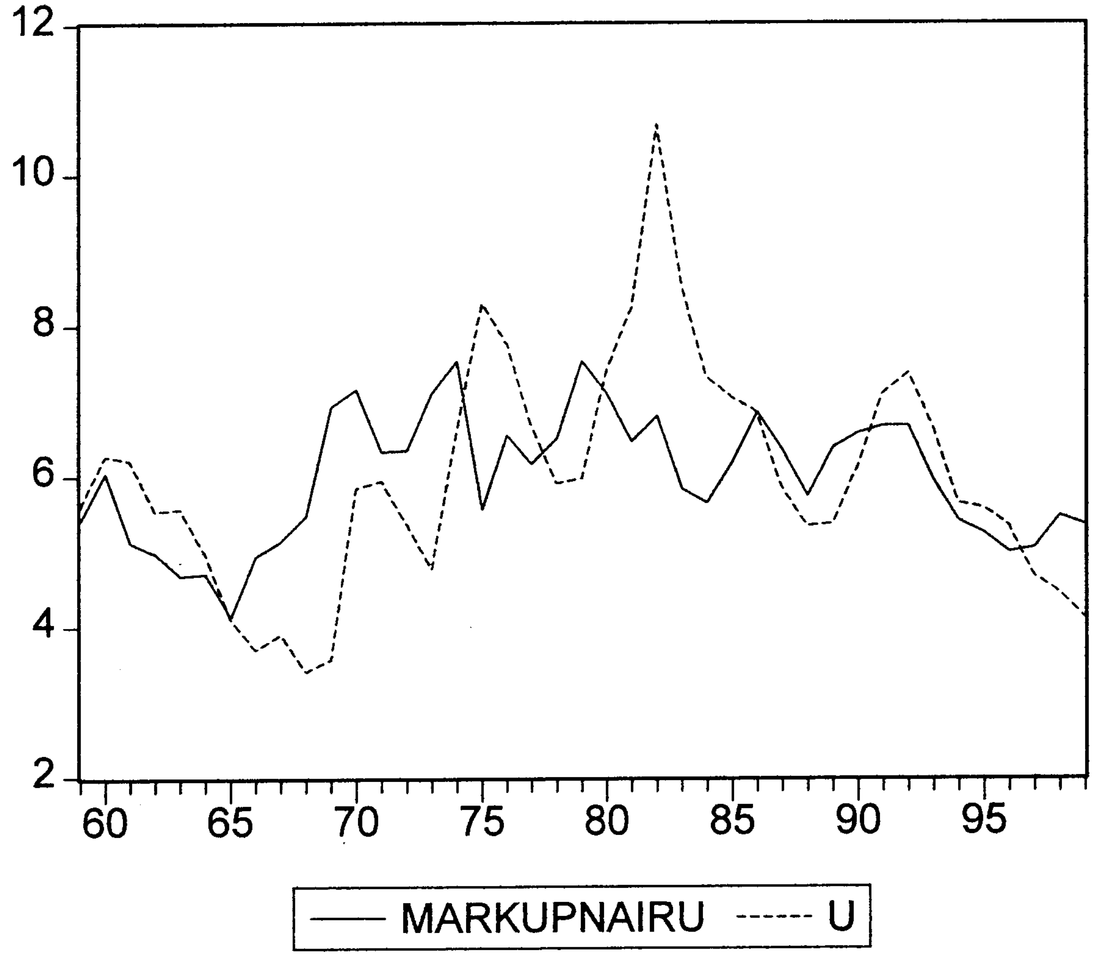


FIGURE 11. The Markup TV-NAIRU and the Unemployment Rate (Non-Farm Business Sector)

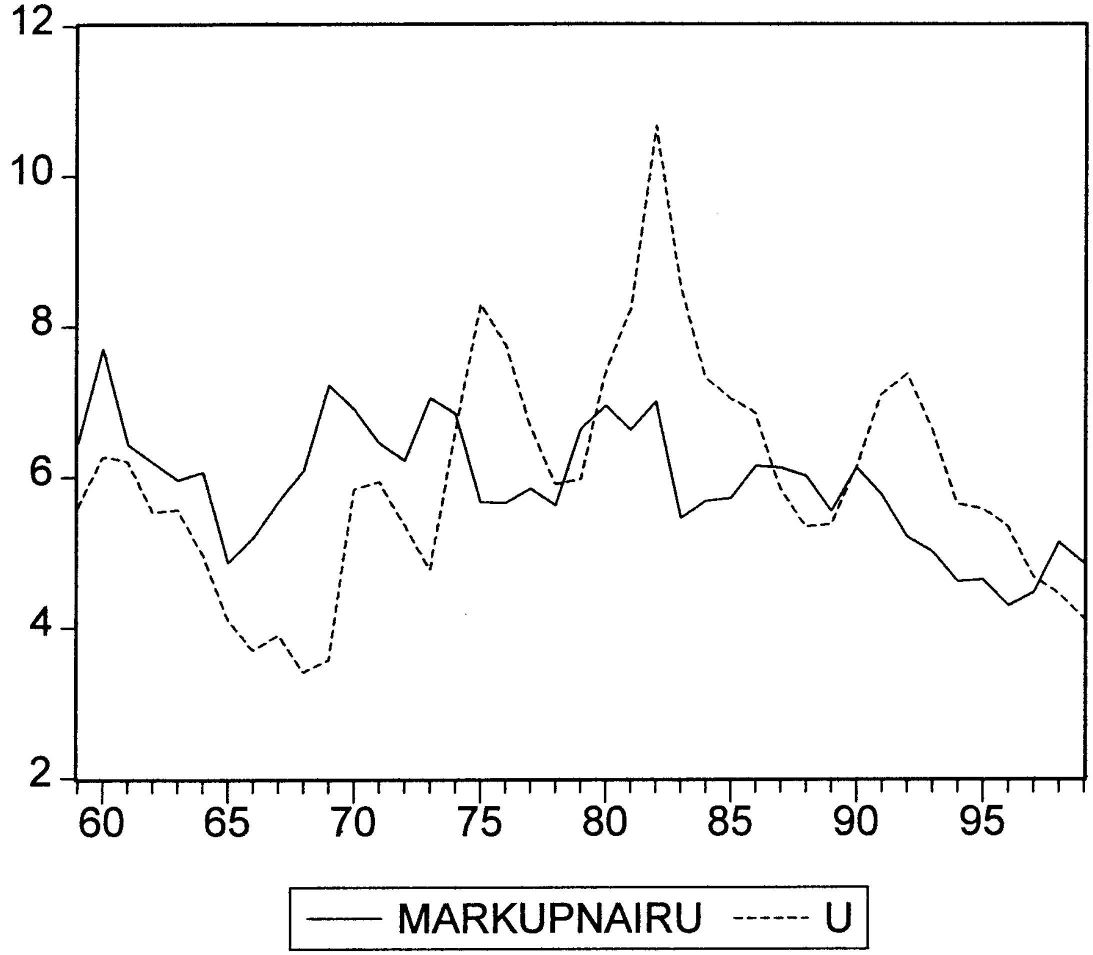


FIGURE 12. Comparison of the Markup and Kalman-Filter TV-NAIRUs (Non-Financial Corporate Sector)

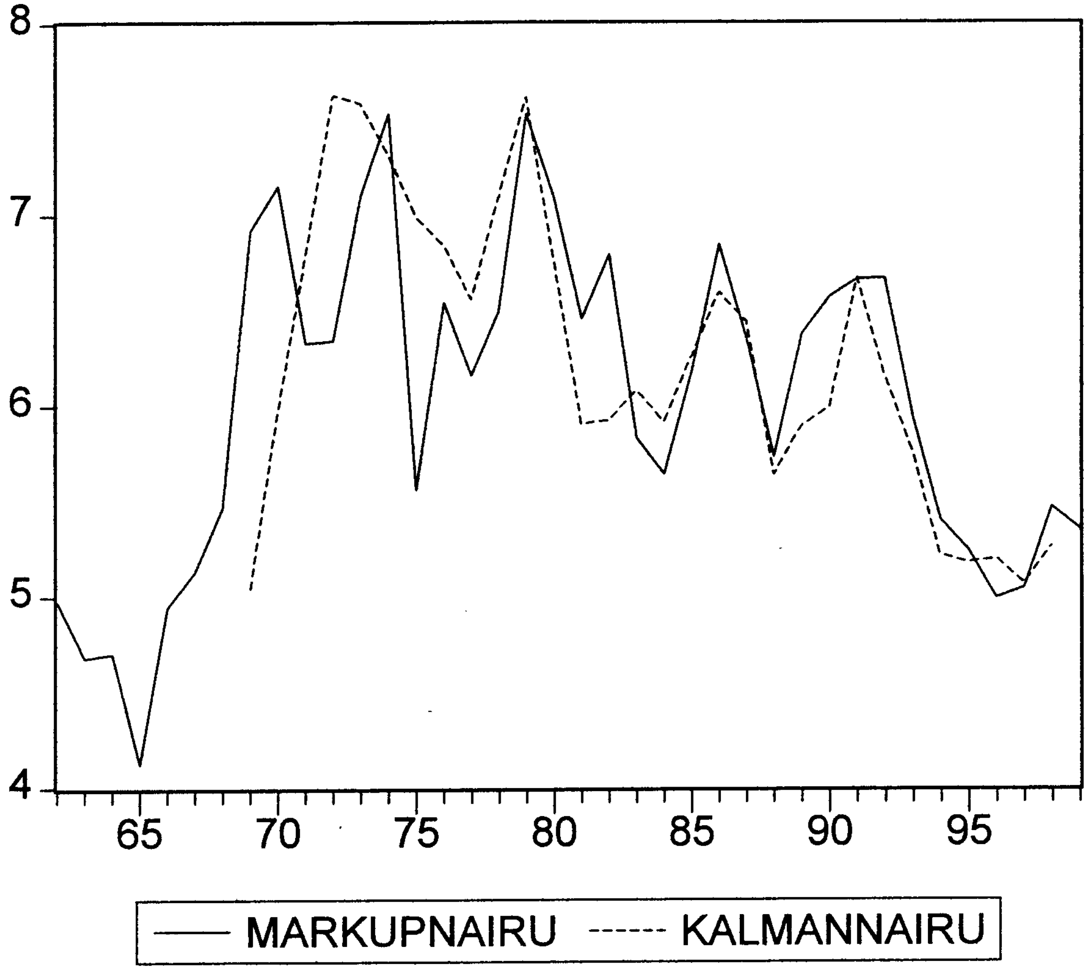


FIGURE 13. Comparison of the Markup and Kalman-Filter TV-NAIRUs (Non-Farm Business Sector)