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ABSTRACT

Using quarterly macro data and annual state panel data, we examine various explanations of the low rate of price inflation, strong real wage growth, and low rate of unemployment in the U.S. economy during the late 1990s. Many of these explanations imply shifts in the coefficients of price and wage Phillips curves. We find, however, that once one accounts for the univariate trends in the unemployment rate and in the rate of productivity growth, these coefficients are stable. This suggests that many explanations, such as persistent beneficial supply shocks, changes in firms' pricing power, changes in price expectations arising from shifts in Fed policy, and changes in wage setting behavior miss the mark. Rather, we suggest that explanations of movements of wages, prices and unemployment over the 1990s, and indeed over the past forty years, must focus on understanding the univariate trends in the unemployment rate and in productivity growth and, perhaps, the relation between the two.

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1. Introduction

One of the most salient features of the U.S. expansion in the second half of the 1990s was the combination of low price inflation, strong real wage growth, and low and falling unemployment. On its face, this runs counter to the postwar U.S. experience that periods of low unemployment and strong wage growth are associated with rising rates of inflation. This paper undertakes an empirical investigation of the extent to which changes in price setting behavior, changes in wage setting behavior, and fundamental changes in product and labor markets led to this happy coincidence.

The facts are summarized in figure 1. Figure 1a is a scatterplot of the change in the annual rate of price inflation, as measured by the GDP deflator, vs. the unemployment rate in the previous year, from 1960 – 1999; for example, the point labeled "98" indicates the unemployment rate in 1998 and the change in the rate inflation from 1998 to 1999. Figure 1b is a comparable scatterplot, except that the series on the vertical axis is the annual percentage growth rate of real wages, as measured by compensation per hour in the nonfarm business sector, deflated by the GDP deflator. The regression line estimated using data from 1960-1992 is plotted in both figures. These regression lines are simple estimates of the price and wage Phillips curves. The NAIRU is defined to be the value of the unemployment rate at which the price regression predicts no change in inflation, which corresponds to the intersection of the regression line and the horizontal line in figure 1a. Alternatively, the wage-based NAIRU is the value of the unemployment rate at which the wage regression line predicts real wage growth that coincides with the growth in labor productivity, which is given by the intersection of the regression line and the horizontal line in figure 1b.

Three features are evident from these scatterplots. First, both the wage and price Phillips curves reflect a negative correlation between the unemployment rate in one year and inflation in the next: the correlation in figure 1a for the 1960 – 1992 sample is -0.55, and the correlation in figure 1b is -0.65. Second, the data for 1993 – 1999 (highlighted in the figure) are peculiar, relative to the earlier data: although unemployment fell from 7.5% in 1992 to 4.1% in 1999, the rate of price inflation was essentially constant over this period (it fell by an average of 0.1% per year). Third, from 1993 to 1999 real wages increased substantially: real wages grew by an average of 1.5% over this period, consistent with little if any shift in the NAIRU in this wage scatterplot and, if anything, a steeper wage Phillips curve regression line.

The theories that have been proposed to explain these events fall into two groups: theories in which "The Phillips curve is alive and well but…" and those that proclaim that "the Phillips curve is dead."

Most of the proposed theories are in the "alive and well but…" group. According to these theories, the price Phillips curve – the regression line in figure 1a – continues to have a negative slope, but it has been shifting inwards. Such a shift is indicated by the arrow and dashed line in figure 1a. Similarly, the strong growth of real wages in the late 1990s in figure 1b is attributed by these theories to the surge in productivity: workers are reaping the rewards of using more powerful tools. The differences among these theories arise in the particulars of how they explain the inward shift of the price inflation Phillips curve: some focus on price setting behavior of firms, others focus on labor markets, while others suggest that we simply have been the lucky recipients of favorable supply shocks (falling energy prices and favorable terms of trade shocks).

The theories that focus on pricing behavior have several variants. One is that globalization has increased competition in the product market, thereby squeezing markups and yielding one-time reductions in markups and prices (e.g. Brayton et. al. [1999]). Similar arguments can be made about the possible effect of the Internet on price competition for some goods. A different argument is that the credibility of the commitment of the Federal Reserve Board to controlling inflation has increased, and that this has had the effect of reducing expected inflation which in turn moderates actual price increases posted by producers.

The theories that focus on labor markets suggest that the source of the inward shift in the Phillips curve lies with a decline in the natural rate of unemployment. Several such theories are surveyed and analyzed empirically in Katz and Krueger (1999). Some emphasize changes in how people look for work (using temporary help firms, using the Internet, etc.). Others emphasize changes in the composition of the work force, including the aging of the workforce as the baby boom enters an age traditionally associated with high degrees of labor force attachment, the entry of "welfare mothers" into the workforce as a consequence of welfare reform, and the removal of many marginal workers from the workforce either because of incarceration (Katz and Krueger [1999]) or because of relaxed Social Security Disability Insurance (SSDI) provisions (Autor and Duggan [2000]).

Finally, some of these theories stress the role of good luck. For much of the 1990s, energy prices were declining and the U.S. enjoyed a strong dollar. Gordon (1998) explored these sources in detail, and concluded that they explain part, but far from all, of the price inflation/unemployment puzzle of the 1990s.

In contrast, "The Phillips Curve is dead" theories interpret the 1990s not as an inward drift in the Phillips curve, but rather as a fundamental change in the relation between unemployment and inflation. According to these theories, it is the slope of the Phillips curve that has shifted, not the intercept: the Phillips curve now is the dotted line in Figure 1a, which was fit to the data from 1993 – 1999. This curve has a slope of zero. This more radical interpretation requires more radical theories. The popular press versions of these theories stress that increased price competition in the new economy prevents firms from responding to market tightness by increasing prices, thereby eliminating any relation between measures of aggregate activity, such as unemployment, and changes in the rate of price inflation.

Subtler versions of these theories involve nonlinearities in firm behavior when inflation is low. Akerlof, Dickens and Perry (1996) suggest that reluctance by firms to give negative nominal wage cuts means that steady state hiring depends on the rate of inflation; in particular, the equilibrium unemployment rate falls when inflation falls. Taylor (2000) develops a different theory of state-dependence of the NAIRU; in his model, low inflation itself leads firms to expect reduced pricing power, which in turn contributes to reduced inflation and reduces the sensitivity of inflation to growth in demand. Akerlof, Dickens and Perry (2000) provide a model of price setting in which some firms find it convenient to predict zero inflation as long as inflation is low, permitting the unemployment rate to be persistently low without igniting inflation. Empirically, this is the same thing as the NAIRU falling when the inflation rate gets low.

In all three of these models, the NAIRU is not *permanently* low, but rather its low value is contingent upon the monetary authority holding down inflation.

This paper has two objectives. The first, more modest one is to document the shifts in Figure 1. To a considerable extent, this entails updating earlier estimates of Phillips curves and NAIRUs along the lines of Staiger, Stock and Watson (1997a, 1997b) and Gordon (1998). The second, more ambitious objective is to provide new evidence, based on quarterly macro data and on a panel of annual data for U.S. states from 1979 – 1999, that helps us to parse the theories outlined above or, at least, to rule out some families of theories.

We do this by addressing three specific questions. First did the Phillips curve break down in the 1990s, or did it simply shift, with a new and evolving NAIRU? That is, which class of theories – "the Phillips curve is dead" or "the Phillips curve is alive, but…" has more empirical support? We conclude that the weight of the evidence supports the "alive but…" group of theories: the evidence suggests that the price Phillips curve has shifted in, not flattened out.

This leads to the second question: why has the price Phillips curve shifted in? That is, does the empirical evidence help to distinguish between the many theories of the inward drift in the price Phillips Curve? In our view, the weight of the empirical evidence points towards explanations that involve special features in labor markets. The macro evidence suggests that changes in price setting behavior cannot explain the broad stability of the relation between price inflation and measures of economic activity. Rather, the explanation for the shifting unemployment Phillips curve seems to lie in declines in the univariate trend rate of unemployment.

The third question, then, is whether labor productivity gains during the 1990s can explain the apparently aberrant recent behavior of real wages in Figure 1b. That is, is the wage Phillips curve as resilient empirically as the price Phillips curve, once we have accounted for productivity? Our answer is yes: adjusting for trend labor productivity gains accounts for the discrepancies that otherwise appear between the price and wage Phillips curves.

In short, once one allows for the *univariate* trends in the unemployment rate and the rate of productivity growth, the 1990s present no wage or price puzzles. Backward looking price Phillips curves are stable when the unemployment rate is specified as a gap, that is, as the deviation from its univariate trend value. Similarly, wage Phillips curves are stable when wages are adjusted for changes in trend productivity growth and when the regressions are specified using activity gaps. This implies that theories of the 1990s that focus on favorable supply shocks, changes in pricing power of firms and markups, or changes in the negotiating power of labor all miss the mark, for these theories imply persistent errors and/or coefficient instability that we fail to find. Rather, this evidence points to underlying economic forces that change the univariate trends of the unemployment rate and the growth rate of productivity. Unfortunately, our regressions using the state data fail to isolate any economic or demographic determinants of the trend unemployment rate.

The plan of the paper is as follows. Sections 2 – 5 analyze quarterly U.S. macro data from 1960 – 2000. We begin in section 2 by estimating the long-run trends in the macro data and discussing how we estimate output gaps. Section 3 addresses issues of econometric specification and estimation of the price and wage Phillips curves and associated time-varying NAIRUs (TV-NAIRUs). These Phillips curves are specified using output gaps, which are the difference between the output measure and its low frequency univariate trend component. As Hall (1999) and Cogley and Sargent (2001) argue, the low frequency trend component can be thought of as an estimate of the natural rate of unemployment; thus this approach allows separate identification of the NAIRU and the natural rate. Section 4 reports empirical price Phillips relations estimated both with the unemployment rate gap and with gaps based on other measures of economic activity. Consistent with the findings in Staiger, Stock and Watson (1997a), Stock (1998) and Stock and Watson (1999b), we find stability and predictive content in these broader measures, which suggests that the "Phillips curve is dead" theories are premature. In section 5, we turn to wage Phillips curves and examine the role of productivity gains in explaining the recent rise in real wages.

Sections 6-9 focus on the state panel data. Although some authors in this literature have used state level data (notably Katz and Krueger [1999] and Lerman and Schmidt [1999]), their use has been limited and we are able to consider a large number of new variables and, accordingly, to use the state data to examine the various theories. Specifications and econometric issues, including our instrumental variables (IV) method for alleviating errors-in-variables bias arising from using the state data, are discussed in section 6. The data set is described in section 7, and benchmark results are presented in section 8. Section 9 reports results of using additional variables to explore the stability of the Phillips curve and to examine theories about sources of shifts in the NAIRU. Conclusions are summarized in section 10.

A remark on terminology is in order before proceeding. In conventional usage, the "NAIRU" is the rate of unemployment consistent with price inflation remaining constant; the "NAWRU" is the rate of unemployment consistent with wage inflation remaining constant; and the "NAIRCU" is the rate of capacity utilization consistent with price inflation remaining constant. In this paper, we consider both wage and price inflation and consider other activity indexes, including building permits and demographically adjusted unemployment. We could, then, report TV-NAWRCUs, TV-NAIRBPs, TV-NAWRDUs, and so on. But we do not find these acronyms helpful. Instead, we shall call them all TV-NAIRUs and, when needed, shall add specificity through the use of adjectives.

2. Trends in the Macro Data

2.1 Method for Estimating Univariate Trends and Constructing Gaps

Let y_t be a quarterly time series, and let y_t^* denote its trend. Unless explicitly noted otherwise, y_t^* is estimated by passing y_t through a two-sided low pass filter, with a cutoff frequency corresponding to 15 years. Essentially, this estimates y_t^* as a long two-sided weighted moving average of y_t with weights that sum to one. Estimates of the trend at the beginning and end of the sample are obtained by extending (padding) the series with autoregressive forecasts and backcasts of y_t, constructed from an estimated AR(4) model (with a constant term) for the first difference of y_t. The "gap" value of y_t, y_t^g, is defined to be the deviation of y_t from its trend value; that is, $y_t^g = y_t - y_t^*$. Thus, the trend value of the unemployment rate is the value of the unemployment rate resulting from the low pass filter, and the unemployment gap is the difference between the actual unemployment rate and the long run trend in unemployment.

2.2 Description of the Aggregate U.S. Data

The U.S. data are quarterly from 1959:I to 2000:II. The primary price measure is the GDP deflator, but in our sensitivity analysis we also consider the personal consumption expenditure (PCE) deflator, the Consumer Price Index (CPI) and the deflator for the nonfarm business component of GDP . All rates of inflation are computed as $\pi_t = 400\ln(P_t/P_{t-1})$, where P_t is the level of the price index in quarter t. For our Phillips curve specification, recent values of π_t are adjusted for recently implemented bias corrections, as suggested by Gordon (1998). Details are provided in the appendix.

Several measures of wages are used. Our primary measure is compensation per hour in the nonfarm business sector. For sensitivity checks, we also consider the Employment Cost Index (both total compensation and wages and salaries only), average hourly earnings of nonagricultural production workers, and compensation per hour in manufacturing. Wage growth rates are computed as $\omega_t = 400\ln(W_t/W_{t-1})$, where W_t is the level of the wage index.

Labor productivity is measured by output per hour of all workers in the nonfarm business sector, except when we consider compensation per hour in manufacturing, in which case labor productivity is measured by output per hour of all workers in manufacturing.

Economic activity is variously measured by the total unemployment rate, a demographically adjusted unemployment rate, the rate of capacity utilization, and housing starts (building permits). The demographically adjusted unemployment rate was constructed as weighted average of the unemployment rates for 14 age-gender categories (ages 16-19, 20-24, 25-34, 35-44, 45-54, 55-64, 65+, each by male/female), weighted by the shares of each age group in the 1985 labor force.

Supply shock variables in the Phillips curve regressions are Gordon's (1982) price control series, the relative price of food and energy, and exchange rates.

Data sources for all series are given in the Data Appendix.

2.3 Low Frequency Properties of the Data

Figure 2 presents quarterly time series data and their estimated trends for (a) price inflation (GDP deflator), (b) wage inflation (compensation per hour), (c) real wage growth (compensation per hour deflated by GDP deflator inflation), (d) labor productivity growth, (e) the unemployment rate, (f) the demographically adjusted unemployment rate, (g) building permits (housing starts), and (h) the rate of capacity utilization. The "gaps" of each of these variables is the difference between the quarterly data and their estimated trends. Table 1 shows the sample mean of each of these series over each of the four decades in the sample and, as a measure of persistence in the series, a 95% confidence interval for the largest root in a univariate autoregression with six lags.

Figure 2 and table 1 show several important features of these data. First consider wages, prices and productivity. Figures 2a and 2b show substantial low-frequency (trend) variability in price and nominal wage inflation. As shown in table 1, this low frequency variability leads to confidence intervals for the largest AR root that range from 0.90 to 1.02 (which, notably, include a unit AR root). Nominal wage growth less productivity growth is also persistent: the confidence interval for its largest AR root is 0.81 to 1.00.

In contrast, real wage growth and, especially, real wage growth less productivity growth are considerably less persistent, and 95% confidence intervals for their largest AR roots do not include unity. Still, the decade-long averages in real wages show considerable variability, and the ratio of the largest to the smallest decadal average varies by a factor of more than 2.5. Table 1 shows that these decade-long changes in real wage growth rates are broadly consistent with movements in the growth of labor productivity: real wage growth and labor productivity growth were both high in the 60's, low in the 80's, etc. The relationship is stronger when wages, prices and productivity all pertain to the non-farm business sector than when the GDP deflator is used to construct real wages. Average real wage growth adjusted for productivity changes little over the decades in the sample.

Formally, the hypothesis of a unit root in productivity is rejected, which taken literally indicates that productivity growth is stationary. This characterization, however, does not allow for the possibility of slowly changing mean productivity growth rates that lie at the heart of the new economy debate. From a statistical point of view, if there is a highly persistent component of productivity growth but its variance is small relative to variations induced by cyclical movements and measurement error, then it will be difficult to detect and the series can spuriously appear to be stationary.

These results are consistent with price inflation and nominal wage inflation adjusted for productivity growth sharing a common stochastic trend that disappears from real wage growth adjusted for productivity growth. In the terminology of integration and cointegration, this suggests that price inflation is integrated of order 1 (is I(1)), wage inflation less productivity growth is I(1), and real wage growth less productivity growth is I(0); that is, price inflation is cointegrated with wage inflation less productivity growth, with a cointegrated vector of (1, -1).[1]

Consistent with this specification, the *level* of productivity adjusted real wages (equivalently, the "markup" or "labor's share") appears to be I(1). When real wages are computed using the GDP deflator, there is a marked downward trend in the markup, but when the GDP deflator is replaced by the non-farm business deflator, much of the trend disappears. In either case, the series is very persistent and a unit autoregressive root cannot be rejected.

The unemployment rate, building permits (housing starts) and capacity utilization are shown in Figures 2e-2h. The unemployment rate trend exhibits large variability (Figure 2e), and most of this variability remains in the demographically adjusted unemployment rate (Figure 2f). In contrast, the trends in building permits and capacity utilization (Figures 2g and 2h) show much less variability. Table 1 indicate that the unemployment rate series are much more persistent than the building permits and capacity utilization series: unit autoregressive roots cannot be rejected for both unemployment series, but can be rejected for both building permits and capacity utilization.

In summary, these statistics suggest that price inflation and nominal wage inflation, adjusted for productivity growth, are cointegrated. Real wages and productivity

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[1] Application of the Horvath-Watson (1995) test rejects the null hypothesis of noncointegration of these two series against the alternative that they are cointegrated with the cointegrating vector of (1, -1) at the 1%

growth move together at low frequencies, although these movements are small in magnitude compared with the noise and cyclical movements in these series. The unemployment rate and the demographically adjusted unemployment rate appear to be I(1), but capacity utilization and building permits are I(0).

3. Specification and Estimation of Macro Price and Wage Equations

3.1 Specification

Our specifications and estimation methodology follows along the lines of Gordon (1982), King, Stock and Watson (1995), Staiger, Stock and Watson (1997b), and Gordon (1998), with some modifications.

Because prices and wages are codetermined and because we will examine both price and wage Phillips curves, it is useful to consider these curves as a system. The discussion of Section 2.3 suggests that it is fruitful to treat wage inflation and price inflation as a cointegrated system, in which each variable being integrated of order one and having the single cointegrating vector implying that real wage growth net of productivity growth is integrated of order zero.

Motivation from a system without lag dynamics. Let π_t denote the rate of price inflation, let ω_t be the rate of nominal wage inflation (the growth rate of nominal wages), and let θ_t be the growth rate of labor productivity (all expressed in units of percentage annual growth rates). Let x_t be a demand gap variable, for example the output gap or the unemployment gap constructed using the method of Section 2.1. Let Z_t be a vector of

significance level (the test statistic was computed with four lags).

mean zero variables representing observable supply shocks (such as shifts in the relative prices of food and energy) that might affect wage and price setting and thus might enter either the wage or price equations.

The price equation relates the deviation of future inflation from its expectation to the activity gap and supply shocks. Ignoring lags for the moment, this is,

$$\pi_{t+1} - \pi^e_{t+1} = \mu_\pi + \beta_\pi x_t + \gamma_\pi Z_t + v_{\pi t+1}. \tag{3.1}$$

where π^e_{t+1} is the inflation in period t+1 that is expected as of period t, μ_π, β_π, and γ_π are unknown coefficients, and $v_{\pi t+1}$ is an error term.

Implementation of (3.1) requires specifying inflationary expectations. Following an old convention (cf. Gordon [1990, 1998] and Fuhrer [1995]) we restrict attention to the random walk model of expectations, so that $\pi^e_{t+1} = \pi_t$ and $\pi_{t+1} - \pi^e_{t+1} = \Delta\pi_{t+1}$, where $\Delta\pi_{t+1} \equiv \pi_{t+1} - \pi_t$. Making this modification, we have,

$$\Delta\pi_{t+1} = \mu_\pi + \beta_\pi x_t + \gamma_\pi Z_t + v_{\pi t+1}. \tag{3.2}$$

The wage equation is obtained similarly. Again ignoring lags, we have

$$\omega_{t+1} - \omega^e_{t+1} = \mu_\omega + \beta_\omega x_t + \gamma_\omega Z_t + v_{\omega t+1}. \tag{3.3}$$

Various approaches are available for modeling expected nominal wages. We model expected wage inflation as the sum of expected price inflation and expected productivity growth, that is, $\omega^e_{t+1} = \pi^e_{t+1} + \theta^e_{t+1}$. As in the price equation, we suppose that that $\pi^e_{t+1} = \pi_t$. If productivity growth is a random walk, then we can let $\theta^e_{t+1} = \theta_t$. However, productivity growth has a cyclical component, so an alternative method used by Gordon (1998) is to model $\theta^e_{t+1} = \theta^*_t$, where θ^*_t is trend productivity growth. We will use this latter approach as the base specification, but will also report results based on the alternative specification in which $\theta^e_{t+1} = \theta_t$. This leads to a specification of the wage equation of,

$$\omega_{t+1} - \theta^*_t - \pi_t = \mu_\omega + \beta_\omega x_t + \gamma_\omega Z_t + v_{\omega t+1}, \qquad (3.4)$$

Incorporation to lag dynamics. The specifications (3.2) and (3.4) omit lag dynamics. Our treatment of dynamics is motivated by the observation, made in section 2.3, that nominal wage growth less productivity growth, or less trend productivity growth, appears to be cointegrated with price inflation. That is, $\omega_{t+1} - \theta^*_t$ and π_t are arguably cointegrated. This leads to the triangular representation of cointegrated variables, in which x_t and Z_t are treated as exogenous variables:

$$\Delta\pi_{t+1} = \mu_\pi + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi\omega}(L)(\omega_t - \theta^*_{t-1} - \pi_{t-1}) + \beta_\pi x_t + \alpha_{\pi x}(L)\Delta x_t + \gamma_\pi Z_t + v_{\pi t+1}, \qquad (3.5)$$

$$\omega_{t+1} - \theta^*_t - \pi_t = \mu_\omega + \alpha_{\omega\pi}(L)\Delta\pi_t + \alpha_{\omega\omega}(L)(\omega_t - \theta^*_{t-1} - \pi_{t-1}) + \beta_\omega x_t + \alpha_{\omega x}(L)\Delta x_t + \gamma_\omega Z_t + v_{\omega t+1}. \qquad (3.6)$$

where μ_π, β_π, etc. are coefficients and $\alpha_{\pi\pi}(L)$, etc. are lag polynomials. Specifications (3.5) and (3.6) allow lagged effects of x_t but, following the literature, not of the supply shock variable Z_t.

These two specifications form the basis for our time series analysis. The price equation differs from most Phillips curve specifications because it includes a term allowing feedback from real wages net of productivity to future price changes. The wage equation also allows for feedback from price changes to future wage changes. Our motivation for these equations has been to move from the static system (3.2) and (3.4) using the tools of cointegration theory. Note however that our resulting equations are the same as the general specification considered by Gordon (1998, equations (7) and (8)).[2]

An alternative specification that we explore in the empirical section adds a lag of the *level* of productivity adjusted real wages ($\ln(W_{t-1}/P_{t-1})$-$\ln(Productivity_{t-1})$) to the right hand side of (2.5) and (2.6). This specification, a version of which goes back to the classic paper by Sargan (1964), is appropriate when this term is *I(0)*. As the analysis in the last section suggested, this assumption seems at odds with the data used here, but versions of the specification has been used for both wage and price equations using data from the U.S. and other countries (c.f. Barlow and Stadler (undated), Blanchflower and Oswald (1994), Brayton, Roberts and Williams (1999), and Holden and Nymoen (1999).) Blanchard and Katz (1997) (and references cited there) contain a useful of discussion of this specification as it applied to the wage Phillips curve, and we will discuss this issue more in the context of the state Phillips curves specified in section 6.

3.2 Estimation of TV-NAIRUs

Specifications (3.5) and (3.6) use the "gap" variable x_t, constructed as difference between the activity variable and its univariate trend, but what should appear in the Phillips curve is the deviation between the variable and the NAIRU. So, if the univariate trend and the variable's NAIRU are different, then (3.5) and (3.6) should include another term that captures this difference. We model the difference between the NAIRU and the univariate trend as a time varying intercept in these Phillips curves, and estimate this difference from estimates of the time varying intercept.

To make this clear, consider the system in which the activity measure is the rate of unemployment, u_t, and let u_t^N denote the possibly time-varying NAIRU. If the NAIRU does not equal the univariate trend u_t^*, then (3.5) is properly specified as

$$\Delta\pi_{t+1} = \mu_\pi + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi\omega}(L)(\omega_t - \theta_{t-1}^* - \pi_{t-1}) + \beta_\pi(u_t - u_t^N) + \alpha_{\pi u}(L)\Delta(u_t - u_t^N) + \gamma_\pi Z_t + v_{\pi t+1}$$

$$\cong (\mu_\pi + \beta_\pi[u_t^* - u_t^N]) + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi\omega}(L)(\omega_t - \theta_{t-1}^* - \pi_{t-1}) + \beta_\pi u_t^g + \alpha_{\pi u}(L)\Delta u_t + \gamma_\pi Z_t + v_{\pi t+1} \quad (3.7)$$

where $u_t^g = u_t - u_t^*$ is the unemployment gap where second equation makes the approximation that, because u_t^N is slowly varying, the term $\alpha_{\pi u}(L)\Delta u_t^N$ is negligible. Thus, to the extent that the univariate trend in unemployment u_t^* differs from the NAIRU

[2] Gordon's (1998) derivation differs from ours, and he does not discuss cointegration explicitly. However, by imposing sums of coefficients in his lag polynomials to equal one (which he does in his empirical work), the resulting system is equivalent to (3.2) and (3.4) which in turn implies that the system is cointegrated.

u_t^N, the gap specification (3.5) will have a time varying intercept. An identical argument applies to the wage equation (3.6).

This reasoning leads to a modification of the system (3.5) and (3.6), in which the intercepts are allowed to vary over time:

$$\Delta\pi_{t+1} = \mu_{\pi t} + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi\omega}(L)(\omega_t - \theta_{t-1}^* - \pi_{t-1}) + \beta_\pi u_t^g + \alpha_{\pi x}(L)\Delta x_t + \gamma_\pi Z_t + v_{\pi t+1}, \quad (3.8)$$

$$\omega_{t+1} - \theta_t^* - \pi_t = \mu_{\omega t} + \alpha_{\omega\pi}(L)\Delta\pi_t + \alpha_{\omega\omega}(L)(\omega_t - \theta_{t-1}^* - \pi_{t-1}) + \beta_\omega u_t^g + \alpha_{\omega x}(L)\Delta x_t + \gamma_\omega Z_t + v_{\omega t+1}. \quad (3.9)$$

If the slope coefficients are stable, any intercept drift in these equations arises from a departure of the NAIRU from the trend unemployment rate.

Our method for estimating the intercept drift follows King, Stock and Watson (1995), Staiger, Stock and Watson (1997b), and Gordon (1998) and adopts an unobserved components model for the intercept, in which the intercept follows a random walk:

$$\mu_{\pi t+1} = \mu_{\pi t} + \eta_{\pi t+1}, \text{ where } \eta_{\pi t+1} \text{ is i.i.d. } N(0, \sigma_{\eta_\pi}^2) \quad (3.10)$$

$$\mu_{\omega t+1} = \mu_{\omega t} + \eta_{\omega t+1}, \text{ where } \eta_{\omega t+1} \text{ is i.i.d. } N(0, \sigma_{\eta_\omega}^2) \quad (3.11)$$

The random walk specification is flexible way to track smooth changes in the intercept. The initial condition for the random walk is identified by the unconditional means of the regressors, so we construct the regressors to have mean zero and initialize the random walk around zero.

According to the system (3.8) and (3.9), time variation in the wage and price equation intercepts arises from changes in $u_t^* - u_t^N$, and this means that the innovations $\eta_{\pi t+1}$ and $\eta_{\omega t+1}$ should be the same. We shall examine this by estimating the intercept drift separately for the price and wage equations and comparing the results. In addition, we shall (separately) test the hypotheses that $\sigma^2_{\eta_\pi}$ = 0 and $\sigma^2_{\eta_\omega}$ = 0 using the QLR or sup-Wald test (Quandt [1960], Andrews [1993]). The parameters $\sigma^2_{\eta_\pi}$ can be estimated by maximum likelihood, but the MLE has a distribution that piles up at zero when these are small and is thus unsatisfactory. Instead we construct confidence intervals and median-unbiased estimates of $\sigma^2_{\eta_\pi}$ and $\sigma^2_{\eta_\omega}$ using the methods in Stock and Watson (1998), as discussed in Staiger, Stock and Watson (1997b) and Stock (1998, 1999).

The estimate of the NAIRU, $\hat{u}_t^N$ based on one of these estimated equations is obtained by combining the univariate drift and the intercept drift. Because $\mu_{\pi t} = \beta_\pi(u_t^* - u_t^N)$ (with mean zero regressors), we have the estimator,

$$u_{t|T}^N = u_t^* - \frac{\mu_{\pi t|T}}{\hat{\beta}_\pi}, \qquad (3.12)$$

where $\hat{\beta}$ is the estimator of β and $\mu_{\pi t|T}$ is the estimator of $\mu_{\pi t}$ obtained from the Kalman smoother based on the estimated parameters of the system.

We have motivated this treatment of the parameter drift by observing that we want a consistent framework that is flexible enough to handle activity measures with quite different trends. However, this formulation has two additional advantages. First, it allows separate identification of the univariate trend and the NAIRU. Second, since much of the time variation in the NAIRU is likely to be associated with changes in the trend unemployment rate, the method can be viewed as a device akin to prewhitening to obtain more precise estimates of the TV-NAIRU.

4. Macro Estimates of Price Phillips Curves

4.1 Benchmark Price Regressions

Benchmark estimates of regressions of the form (3.8), using various activity gaps, are reported in table 2. The specifications include standard supply shock variables (Gordon's [1982] series for wage and price controls and the relative price of food and energy). For comparability to conventional specifications, these specifications do not include the error correction term (real wages less trend productivity, ω_t-θ^*_{t-1}-π_{t-1}) or its lags as regressors; these are included in results reported in the next section. The first row reports the estimated value of the coefficient on the level of the activity gap (which is equivalent to the sum of the coefficients on the current and lagged gaps in a specification in which lags of x_t, rather than of Δx_t), its standard error, and the p-value for the sup-Wald statistic testing the stability of this coefficient. The second block of entries report the trend value of the activity measure, and the third block of entries reports the estimated TV-NAIRU (the sum of the univariate trend and the estimated deviation of the trend arising from intercept drift). Standard errors for the NAIRU, and for its change since 1992, are computed using the Kalman smoother standard error formula and do not incorporate estimation error, which would increase them. The final row reports the median unbiased estimate of the standard deviation of the change in the intercept; if the population counterpart of this coefficient is zero, there is no parameter drift, so the TV-NAIRU for that activity measure equals its univariate trend.

Four results are notable. First, the slope coefficient shows the pro-cyclical nature of the change in inflation and is statistically significant in each of these specifications. The estimated value of the slope coefficient in the unemployment specification is comparable to estimates obtained elsewhere in this literature using different sample periods and different series, cf. Staiger, Stock and Watson (1997b, table 1) although they are approximately half the size of the coefficients in Gordon (1998, table 3).

Second, the TV-NAIRU is estimated to have fallen by approximately 1.6 percentage points from 1992 to 2000; the decline is only slightly less if it is measured using the demographically adjusted unemployment rate. In contrast, the NAIRU for capacity utilization and building permits is relatively stable, for example, the decline in the capacity utilization TV-NAIRU is only two-thirds of the Kalman smoother standard error of the estimated decline.[3]

Third, for all practical purposes the estimated NAIRUs are simply the univariate trends in the various activity measures. This can be seen by comparing the selected univariate trend values and the estimated TV-NAIRUs shown in table 2, or the sample paths of these values for the unemployment specification plotted in figure 3. The reason why the TV-NAIRU and trend values are so similar follows from the data analysis in Section 2. Neglecting lags and the supply shocks, the Phillips curve is

[3] Garner (1994) pointed out the stability of Phillips curves specified with capacity utilization estimated with data through the early 1990s. Gordon (1998) and Stock (1998) estimated TV-NAIRUs for capacity utilization and found they were quite stable compared with TV-NAIRUs for the unemployment rate. Our results confirm these findings and extend them through the end of the 1990s.

$$\Delta\pi_{t+1} = \beta_\pi(u_t^g) - \beta_\pi(u_t^N - u_t^*) + v_{\pi t+1} \qquad (4.1)$$

From the data analysis in section 2, $\Delta\pi_{t+1}$ is *I(0)*, and by construction so is the unemployment gap, u_t^g. This means that there cannot be large persistent deviations of u_t^N from u_t^*: if there were, these would be transmitted to $\Delta\pi$, but since $\Delta\pi$ is *I(0)*, it does not contain large persistent movements. Mechanically, this means that in all the specifications, the median-unbiased estimate of the standard deviation of the intercept drift is very small; indeed, it is nearly the same value in each specification, between 0.022 and 0.027. This corresponds to a change in the intercept between .044 and .054 percentage points per year, which is nearly two orders of magnitude less than the standard deviation of the dependent variable, the quarterly change in inflation at an annual rate. In all the specifications, the 90% confidence interval includes 0, so the hypothesis of no parameter drift in these equations cannot be rejected at the 5% significance level.

While the TV-NAIRU and univariate are very similar, figure 3 does show some differences between u_t^N and u_t^*. The deviation in the 1960s and early 1970s is associated with the trend increase in inflation over this period, and the deviation in the early 1980s is associated with a decline in the trend rate of inflation.

The fourth result from table 2 concerns the time variation in the slope of the Phillips curve. The p-values for tests of no slope change range from 0.02 to 0.17, suggesting possible time variation in the slope. To investigate the magnitude and timing of this variation, we estimated a model that allowed to slope coefficient to vary, but held the intercept constant. Specifically, β_π was modeled as a random walk with innovation variance estimated using the method described in Stock and Watson (1998). Figure 4 shows the estimates of the time varying slope coefficients for the specification using the unemployment rate obtained by the Kalman smoother together with ±2 standard error bands and the OLS slope estimate. Most of the time variation evident in the slope occurs in the mid 1970's, and the estimated slope remained essentially unchanged during the 1990's. Similar results obtain using the other variables (capacity utilization, building permits and the demographically adjusted unemployment rate). These results are consistent with some small amount of time variation in the Phillips curves slope over the sample, but little time variation in the past dozen or so years.

4.2 Sensitivity Analysis

Table 3 summarizes 36 alternative Phillips curves regressions that examine the sensitivity of the benchmark results in table 2. These regressions differ by: the price index used to measure inflation; the activity measure used; whether supply shock control variables are included; whether the error correction term and its lags are included; whether the log-level of the productivity adjusted real wage (the "markup") is included; and how many lags are included in the specifications. The statistics reported in the table are the same as in table 2, except that to save space the values of the level of the trend activity measure and the associated TV-NAIRU are not reported; rather only the change in the TV-NAIRU from 1992 to 2000 (and its Kalman smoother standard error, ignoring estimation uncertainty) is reported.

These results suggest eight conclusions.

First, the specifications in which the unemployment rate gap is the activity variable are robust to these changes. The coefficient on the unemployment rate gap is fairly stable, with estimates ranging from -.25 to -.37 across specifications, with all the estimated coefficients within a standard error of –0.3. The TV-NAIRUs estimated with the unemployment rate specifications are all estimated to decline substantially from 1992 to 2000, with the almost all of the estimates being approximately 1.4 to 1.6 percentage points

Second, in virtually all the specifications with alternative activity gaps, the activity gap coefficients are significant at the 5% level (usually at the 1% level). Thus, the evidence is consistent with there being a generalized Phillips relation, where the unemployment rate is only of several possible indicator can be used in this relation.

Third, in virtually all the specifications, the median unbiased estimator of the drift in the intercept term suggests that there is very little drift in the intercept in these regressions. In almost all specifications, the null hypothesis of no parameter drift is not rejected at the 5% significance level.

Fourth, there is also little evidence of substantial time variation in the slope of the Phillips curve. Only a few of the test statistics for time variation are significant at the 5% level (6 of 36), and when time variation is allowed the estimated sample path of the time slope shows little movement over the past decade.[4]

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[4] Brainard and Perry (2000) estimate wage and price Phillips curves allowing for time variation in the coefficients and also find little change in the estimated slope. Their specification differs from ours in several respects; most notably their equations are estimated using the levels of price and wage inflation while we use the change in price inflation and the productivity adjusted real wage. Although their estimates suggest that the coefficients on lagged inflation have changed over time, they do not provide standard errors or any evidence of whether these changes are statistically significant. Doing so in their specification would require handling the persistence of their regressors, in addition to the usual issues arising in time-varying coefficients.

Fifth, the estimate of the 1992 – 2000 change in the TV-NAIRU is largely unaffected by how supply shocks are treated. For example, in the benchmark specification (which includes the supply shock variables), the NAIRU is estimated to decline by 1.59 percentage points, while if the supply shock variables are omitted the NAIRU is estimated to decline by 1.54 percentage points. However, the regression standard errors of the specifications with supply shocks are significantly smaller than those with the supply shock omitted. Evidently these variables are important for explaining one-off changes in inflation, but not the kind of persistent changes that could be confused with a change in the NAIRU.

Sixth, the estimated recent decline in the TV-NAIRU is essentially unaffected by whether the total unemployment rate or the demographically adjusted unemployment rate is used. This is consistent with the discussion in Gordon (1998) and Stock (1999) that although demographic shifts might be associated with increases in the NAIRU in the 1970s, the timing of demographic shifts is not aligned with this sharp recent decline.

Seventh, these results confirm the finding in table 2, columns (3) and (4) that TV-NAIRUs estimated using the rate of capacity utilization and building permits have been relatively stable; for capacity utilization the change from 1992 to 2000 is less than its Kalman smoother standard error.

Eighth, adding the error correction term to the benchmark specification decreases the standard error of the regression slightly but does not change the estimates of the slope coefficient of the TV-NAIRU. This suggests that the estimated decline in the NAIRU is not a spurious consequence of neglecting feedback from wages to prices. Table 3 also shows results for a specification that includes the markup of prices over productivity adjusted wages is included (or equivalently, when we include the log level of the productivity adjusted real wage). Including this variable reduces somewhat the estimated decline of the unemployment NAIRU, from 1.59 percentage points in the base specification to 1.42 in the specification including this term. Thus, this term is estimated to contribute perhaps 0.2 percentage points to the decline in the NAIRU. Taken together, these results suggest that there is limited or no evidence that feedback from wages to prices has particularly served to hold down prices during the 1990s.

4.3 Summary of Main Findings

The regression results in tables 2 and 3 indicate a stable and statistically significant relation between future changes in price inflation and current economic activity as measured by various activity gaps. In addition, in these gap specifications there is very little evidence of drift in the intercept or the slope, either in terms of statistical significance or in terms of the point estimates of the drift from 1992 to 2000. Finally, including supply shocks does not change substantially the estimates of the declines in the NAIRU.

We interpret these findings as being inconsistent with the "Phillips curve is dead" theories of the 1990s. They are inconsistent with theories that place considerable weight on changes in price setting behavior in the 1990s, for these theories would imply important drift in the intercept or slope of the Phillips curve. They also are inconsistent with theories that place great weight on sustained "good luck" in the form of favorable supply shocks. Said differently, once the Phillips curves are specified in gaps, there are no price equation puzzles to explain. Because trend capacity utilization and trend building permits are approximately flat, the only "puzzle" about the price Phillips curve is why the univariate trend in the unemployment rate has fallen. Once we have accounted for the univariate trend in the unemployment rate, these price inflation Phillips curves fit quite nicely throughout the decade and indeed throughout the 1960 –2000 sample period.

5. Macro Estimates of Wage Phillips Curves

This section presents empirical estimates of wage Phillips curves and TV-NAIRUs using the unemployment rate and other indicators of economic activity. The discussion parallels the previous section: section 5.1 presents some benchmark estimates; the robustness of these estimates to alternative specifications are examined in section 5.2; and conclusions are summarized in section 5.3.

5.1 Benchmark Wage Regressions

Benchmark regression estimates. Benchmark wage regressions are reported in table 4, using the same format as table 2.

The most striking result in table 4 is that these specifications are very similar to the benchmark price regressions reported in the corresponding columns of table 2. The slope coefficients in table 4 are larger, but the standard deviation of the dependent variable in table 4 is also larger than in table 2. The slope coefficients are all statistically significant at the 5% level. Although the levels of the TV-NAIRUs are different in table 2 than in table 4 (because the variables have different means), the *changes* in the TV-

NAIRUs are almost the same.[5] For example, the TV-NAIRU based on total unemployment in the price equation in column 1 of table 2 is estimated to decline by 1.59 percentage points from 1992 to 2000; based on the labor share specification in table 4, this decline is estimated to be 1.52 percentage points. The quantitative declines in the TV-NAIRUs are the same for the other activity variables in the two tables.

A key similarity between the price results in table 1 and the wage results in table 4 is that the intercept drift is negligible in both tables. Although the median unbiased estimate is larger in table 4 than in table 2, the dependent variable in table 4 is more variable and the standard error of the regression in the wage regressions is twice that of the price regressions, so the relative variability in the intercept is virtually identical in the price and wage specifications. In all specifications in table 4, the 90% confidence interval for the standard deviation of the change in the intercept includes zero, that is, the hypothesis of no parameter drift cannot be rejected in any of these specifications at the 5% significance level.

Figure 5 plots the estimated TV-NAIRU for unemployment based on the specification in column 1 of table 4, where the TV-NAIRU is adjusted so that it has the sample sample mean as the univariate trend in the unemployment rate (cf. footnote 5). Inspection of this figure underscores that there is effectively no difference between the TV-NAIRU and the univariate trend in unemployment. This is the same conclusion as was drawn from the price TV-NAIRU plotted in figure 3. Comparison of figures 3 and 5

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[5] The difference between the levels of the NAIRUs in price and wage Phillips curve reflects the decline in labor's share over the sample period computed using Nonfarm business (NFB) wages, NFB productivity and the GDP price deflator. This magnitude of this decline is evident from the 10th row of table 1. However, as the last row table 1 shows, there is a much smaller decline when the NFB price deflator is used. Consequently the levels of the NAIRU for the wage Phillips curves using the NFB deflator are closer to the values in the price Phillips curves.

reveals that the TV-NAIRUs estimated from the price Phillips curve in table 2, column 1 and the wage Phillips curve in table 4, column 1 (shifted up per footnote 5) are essentially identical. The reason for this is that, in both specifications, the median unbiased estimate indicates negligible intercept drift.

Table 4 indicates that there is little evidence of changes in the slope of the wage Phillips curve. The p-values for the test of the null hypothesis of no change in the slope ranges from 0.12 to 0.99. Figure 6 shows the estimated values of the time varying slope in the unemployment rate wage Phillips curve using a specification that parallels the results for the price Phillips curve shown in figure 4. The point estimates suggest a slight steepening of the wage Phillips curve over the past decade (consistent with the scatterplot in figure 1b), but the standard error bands make it clear that these changes are far from statistically significant.

5.2 Sensitivity Analysis

Table 5 summarizes results for 48 variations of the wage Phillips curves. Some of these variations are similar to the sensitivity checks reported in table 3, for example changing the definition of the wage series, changing the number of lags, etc. Inspection of table 5 reveals that main conclusions from table 4, particularly the lack of intercept and slope drift in the gap specifications, are robust to these changes. However, there are some important differences among these specifications.

Most notably, these wage specifications are less stable than the price specifications to changes in definitions of the variables. For example, the slope coefficient is often insignificant in specifications in which the GDP deflator is replaced by the PCE deflator or the CPI, as well as in specifications in which wage growth is measured using the ECI (total compensation or wages and salaries) or average hourly earnings. (The sample period for the specifications using the ECI data was limited to 1982-1999.) The results using compensation per hour are, however, consistent with the benchmark results. Overall, however, these results suggest that the presence of a Phillips curve specified using trend unit labor costs are rather delicate.

An important result in table 5 is that replacing trend productivity growth with its sample average growth rate results in coefficients on the activity variable that are essentially unchanged, but induces intercept drift that is both economically large and, now, statistically significant. In contrast to the benchmark estimate, in which the unemployment rate TV-NAIRU is estimated to have fallen by 1.52 percent from 1992 – 2000, the specification using average productivity growth shows a decline of only 0.79 percentage points in the estimated TV-NAIRU. Said differently, when the recent increase in trend productivity is excluded from the specification, the intercept in Phillips curve adjusts to track the increase in real wages. The amount of the required adjustment is large: the change in the intercept implies an increase in the long run mean change in the growth rate of wages by 0.84 percentage points.

5.3 Summary of Main Findings

These regressions point to a stable Phillips relation between trend unit labor costs and the various activity measures over this period, although the macro wage specifications are more delicate than the macro price specifications examined in section 4. When the slope coefficient is precisely estimated, these specifications produce estimates of the 1992 – 2000 change in the TV-NAIRU that are strikingly similar to those produced by the price Phillips curves. In contrast, if the dependent variable is future wage inflation less current price inflation, so that the role of productivity growth is ignored, then the behavior of the wage and price regressions is inconsistent, with real wage inflation appearing in the second half of the 1990s. Specifications of the wage Phillips curves that ignore productivity growth appear unstable in the 1990s, while specifications that incorporate the productivity growth are stable.

6. Specification and Estimation of State Wage Phillips Curves

6.1 Specification of State-Level Wage Phillips Curves

The state regression specifications have the same basic form as the macro regressions, but data limitations lead to several modifications. For example, because the state data are annual, the timing conventions of the quarterly and annual specifications differ. Temporal aggregation by averaging both sides of (3.4) over the four quarters in the year results in a relation between time series with dates that overlap by three quarters. We approximate this by using as the dependent variable ω_{t+1}-θ_{t+1}-π_{t+1} (robustness to different timing conventions is investigated in section 8.2). Also, we use the unemployment rate as the activity variable in all of the state Phillips curves.

These considerations lead to the state-level variant of (3.4),

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \beta(u_{it} - u_{it}^N) + \zeta_t + v_{it+1}, \tag{6.1}$$

where ω_{it+1} is the percentage growth in the nominal wage in state *i* from year *t* to year *t*+1, θ_{it+1} is the annual percentage growth in labor productivity, u_{it} is the unemployment rate, u_{it}^N is the NAIRU for state *i* in year *t* (i.e. the state TV-NAIRU) , ζ_t are macro shocks (the sum of $\gamma_\omega Z_t$ and v_{t+1} in (3.4)), and v_{it} is an error term that has mean zero and which is uncorrelated with the macro shocks ζ_t. The subscript *t* runs over the years in the sample, which differ slightly across specifications depending on data availability. As is discussed in the next section, in our data set state nominal wage growth ω_{it+1} and the unemployment rate u_{it} are computed from the Current Population Survey (CPS). State productivity θ_{it} is constructed in two different ways, either as the annual percentage growth of gross state product, less the growth of state employment, or from national industry-level productivity data weighted by the output share of each industry in the state.

The state TV-NAIRU can usefully be thought of as consisting of several components: the national TV-NAIRU (u_t^N), features that are unique to each state which are constant over the sample such as climate (ϕ_i), and institutional considerations that affect search and matching in the labor market, some of which are measured (X_{it}) and some of which are not (ε_{it}). That is, the state TV-NAIRU can be expressed as,

$$u_{it}^N = u_t^N + \phi_i + \tilde{\gamma} X_{it} + \varepsilon_{it} . \tag{6.2}$$

Substitution of (6.2) into (6.1) and rearranging yields our base state regression specification:

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \gamma X_{it} + v_{it+1}, \tag{6.3}$$

where $\alpha_i = -\beta\phi_i$ are state effects and $\delta_t = \zeta_t - \beta u_t^N$ are time effects.

It is worth making three remarks about the specification (6.3). First, unlike the macro regressions, this benchmark specification for the state panel regressions does not include lags of either the unemployment rate or the labor share. The reason for this is practical: with only twenty annual observations, it is unlikely that we will estimate lag dynamics with any precision, and in any event the lag dynamics will be less pronounced at the annual level than at the quarterly level used in the macro data. In sensitivity checks, however, we report the results of specifications that include lags.

Second, as we discussed above, there is some debate over whether the correct specification of this model should include a lagged wage level on the right hand side – i.e. should the model be specified in terms of wage levels (the "wage curve") or real wage growth less productivity (the Phillips curve)? Specifications using wage growth have the implication that states' productivity-adjusted real wages can drift arbitrarily far apart over long periods, and this is implausible since capital and labor can flow across state boundaries. However, the empirical evidence suggests that capital and labor migrate slowly enough that the Phillips curve specification fits that data better than wage curve specifications with substantial mean reversion (cf., Blanchard and Katz (1992, 1997), Card and Hyslop (1997), Autor and Staiger (in progress)). This leads us to use the Phillips curve as our benchmark specification, although in our sensitivity analysis we consider specifications that include the levels of productivity adjusted real wages.

Third, π_t is not indexed by state in (6.3). This is done because data on prices by state are not available; thus, deflation is done using the national price level (the CPI-U). Because (6.3) includes state effects, this means that the estimates of the slope coefficients β and γ are invariant to which inflation variable is used (CPI, GDP deflator, etc.), whether it is dated t+1 or t, or indeed whether the dependent variable is not deflated at all (i.e. is $\omega_{it+1}-\theta_{it+1}$). The only role of the deflator is to identify the time effects $\{\delta_t\}$ and thereby to identify the macro TV-NAIRU from this state specification.

6.2 Estimation of a National TV-NAIRU from the State Regressions

Estimates of the annual national TV-NAIRU can be obtained from the year effects in the state regressions. The year fixed effects contain movements in the national TV-NAIRU, macro shocks, and estimation error. Thus, these year fixed effects must be filtered to obtain estimates of the national TV-NAIRU.

The filtering strategy used here parallels that used in the macro analysis. That is, the filter is applied so that it estimates the difference between the TV-NAIRU and the univariate trend in unemployment; this univariate trend is then added back in to obtain an estimate of the national TV-NAIRU. Specifically, as noted following (6.3), $\delta_t = \zeta_t - \beta u_t^N$. To maintain consistency with the treatment of the NAIRU in the macro regressions, rewrite this as, $\delta_t + \beta u_t^* = \zeta_t - \beta(u_t^N - u_t^*)$, where u_t^* is the univariate trend in unemployment. Thus,

$$\delta_t + \beta u_t^* = \mu_t + \zeta_t, \tag{6.4}$$

where $\mu_t = -\beta(u_t^N - u_t^*)$.

Equation (6.4) has the same form as (3.9), in the sense that the intercept drift term μ_t arises from the difference between the NAIRU and the univariate trend in unemployment, except that (6.4) has no regressors (the observable and unobservable macro shocks are combined and contained in ζ_t). Accordingly, the national TV-NAIRU is estimated as $u_{t|T}^N = u_t^* + \mu_{t|T}/\hat{\beta}$ (see equation (3.12), where $\hat{\beta}$ is the estimate of β from the state regressions and $\mu_{t|T}$ is the Kalman smoother estimate of μ_t, where μ_t is modeled as following a random walk (as in equation (3.10)), ζ_t is modeled as serially uncorrelated, and the dependent variable in (6.4) is $\hat{\delta}_t + \hat{\beta}u_t^*$, where $\hat{\delta}_t$ are the estimated time effects.

6.3 Instrumental Variables Estimation Strategy

As is discussed in the next section, the state data on unemployment are obtained from the merged outgoing rotation groups (MORG) of the Current Population Survey (CPS). Because many states have a small number of CPS respondents, these estimates are quite noisy, which leads to errors-in-variables bias. To avoid this bias, we use an IV approach. The MORG sample can be split into two independent samples, depending on whether the month is odd or even (although households appear twice in the MORG, the odd and even months have no households in common). Estimates from both the odd and even month samples will be measured with error, but because the samples are randomly drawn the estimation error is independent in these two samples. Thus one set of estimates can be used as an instrument for the other set of estimates. In particular, we use unemployment rates estimated from the even months as in instrument for unemployment rates estimated in the odd months, and vice versa. In some of our specification (e.g. those with lags of the dependent variable) the measurement error will be correlated between the independent and dependent variables as well. Therefore, we replace all variables in the equation (both dependent and independent) with estimates from odd months, and instrument with corresponding estimates from even months.[6]

6.4 Weighting the Observations

There is some ambiguity about whether the state regressions are best estimated by weighting the observations. The sampling error in the dependent variable will be smaller for larger states, but this sampling error is only one component of the error term, so the actual form of heteroskedasticity is unknown. Simple IV (2SLS) has the virtue of taking no stand on the form of this heteroskedasticity, and treats each state as an independent, equally useful experiment. On the other hand, weighting the observations can provide an approximate adjustment for this heteroskedasticity, and if implemented using employment weights it also produces estimates more directly related to aggregate coefficients, in particular the aggregate NAIRU estimates constructed from the state data will reflect population weights. Because of this ambiguity, we report results using both weighted and unweighted observations, where the weights are given the values of state employment.

[6] This instrumenting strategy is simple but statistically inefficient. For an alternative more efficient method see Autor and Staiger (in progress).

7. The State Data Set

Our state-level analysis relies on a dataset containing annual observations on each of 48 states (excluding DC, Alaska and Hawaii) from 1979 to 1999. The annual data on each state were derived from a variety of sources as described below.

7.1 Data Derived from the Current Population Survey

We derive most of our variables, including annual estimates of wages, unemployment, and labor force characteristics for each state, from the merged outgoing rotation groups (MORG) of the CPS. The MORG data are available from 1979 through 1999. One quarter of the CPS sample each month (the outgoing rotation groups) is asked a variety of labor force questions, for a total sample of over 300,000 individuals each year. For each individual who reports being in the labor force, the survey provides the person's labor force status (unemployed or not in reference week), gender, race (white/black/other), gender, marital status (married or not) and age. Education is reported in each year, but because the format of the question changed in 1992 we have recoded the education variable into a set of 10 consistent categories. Most recent industry of employment is reported by all individuals who have worked in the last 5 years, and we collapsed this information into 11 major industries.

For individuals who are currently working, we calculated their hourly wage as usual weekly earnings divided by usual weekly hours. Earnings at the topcode were multiplied by 1.5, and wages below the 1st percentile were set equal to the wage at the 1st percentile. We also calculated whether these persons were self-employed, a union member or covered by a union contract (only available since 1983) or worked as temporary help. To be defined as a temporary help worker, one had to report working in the Personnel Supply Services industry, and report being paid by the hour. This definition is the same as that used by Autor (2001) and Segal and Sullivan (1997), but it is believed that at least 50% of temporary workers misreport their industry in the CPS. Finally, we calculated potential experience as age minus years of education minus 6, where years of education were imputed after 1991 based on the respondent's reported education category, race and gender.

Using the individual-level data for all individuals who were in the labor force from the MORG, we constructed state-level estimates for each year based on three samples: the full MORG, the respondents from even-numbered months, and the respondents from odd-numbered months. Households that appear in the MORG sample in even-numbered months do not appear in the odd-numbered months, so as noted above, that estimation error in these two samples will be independent. In each sample, we constructed weighted estimates for each state and year (using weights provided by the CPS) of the unemployment rate, and the fraction of the labor force in each age, education, race, and gender category. In addition, for employed individuals we calculated the fraction of the workforce in each major industry, working in the temporary help industry, self-employed, and covered by a union contract (or a union member). Finally, we calculated average and median log hourly wages for all workers, for hourly workers, and for full-time workers.

To construct state-level estimates of wages and unemployment that adjusted for changes over time in characteristics of the workforce, we estimated separate cross-section regressions for each year. In particular, for each year we estimated a regression of either unemployment status or the log hourly wage on state fixed effects and controlled for 10 education categories, 3 race categories, a quartic in experience, and an interaction between gender and all other regressors. In addition, controls for 11 major industries were included in the wage equation (but not the unemployment equation). Based on this regression, each state's adjusted mean wage was predicted using that state's intercept and the average value of the covariates in the US over 79-98 period (calculated from the MORG).

7.2 Supplemental State Level Data

In addition to the MORG data, we use a variety of labor market measures that are available by state and year over most of our time period.[7] Data for each state on the UI replacement rate are available through 1998 from the Information Technology Support Center (ITSC) Unemployment Insurance web site (www.itsc.state.md.us). Data on the minimum wage has been derived from various issues of the Monthly Labor Relations Review. Data on the proportion of employment in the temporary services sector comes from county business patterns (this data is only available through 1996, so our specifications use it with a one year lag to avoid losing observations). Finally, the proportion of the population age 25-64 on DI and SSI has been estimated from administrative data and provided to us by David Autor and Mark Duggan.

State estimates of labor productivity growth were derived from data on Gross State Product (GSP) and total full-time and part-time employment (from Table SA25) available from the BEA web site by state and major industry for 1978-1998 (www.bea.doc.gov). For each state, we constructed estimates of labor productivity growth in two ways. Our primary method uses state-level estimates of GSP and employment, and calculates labor productivity growth in each year as $100[\ln(GSP_t/GSP_{t-1}) - \ln(employment_t/employment_{t-1})]$. Our secondary method is to estimate productivity growth in each state as a weighted average of the national-level estimates of labor productivity growth in 11 major industries. National-level estimates of labor productivity growth in each industry were derived from national estimates of GSP and employment as above. Each industry's productivity growth was weighted by the employment share in that industry (as estimated from the MORG) in a given state and year to derive state-level estimates of labor productivity growth.

8. Empirical Sate Wage Phillips Curves

8.1 Benchmark Estimated Phillips Curves

Benchmark wage Phillips curve regressions of the form (6.3) are reported in table 6. These benchmark regressions do not include any structural variables (X_{it}) that might explain the movements in the NAIRU; these variables will be added in section 9.

Four features of table 6 are noteworthy. First, including state effects substantially changes the value of the coefficient on the unemployment rate. Although the state effects are usually jointly insignificant at the 5% level in these and subsequent regressions,

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[7] We thank David Autor for providing us with much of this data.

excluding them evidently introduces omitted variables bias into the estimated slope so henceforth the state effects will be retained.

Second, using IV estimation to mitigate errors in variables bias leads to coefficients on the unemployment rate that are approximately one-third larger than the OLS estimates. This is consistent with the standard measurement error model and its prediction that errors-in-variables biases the OLS estimate towards zero. An important issue in IV regression is whether the instruments are correlated with the variable they are instrumenting; that is, whether they are "weak" or not. When there is a single variable being instrumented, this can be checked by seeing if the F-statistic on the instruments in the first stage regression is at least 10 (Staiger and Stock [1997]). For the regressions in table 6, this first stage F is always at least 100, which gives us confidence in applying standard asymptotic distribution theory to these IV regressions.

Third, the time effects are jointly significant in all specifications.

Fourth, the estimated slope of the state Phillips curve is large and statistically significant. In our preferred specification (IV with state and time effects), the estimated slope is -.59 with a standard error of .11. This estimate is twice what we obtained using the quarterly macro data (-.28 in table 2, column 1), although it is comparable to the macro estimates in Gordon (1998). Because the state regressions control for both time and state effects, these results suggest that idiosyncratic movements in a state's unemployment rate portend large idiosyncratic changes in the rate of growth of real wages.

8.2 Sensitivity Analysis

Tables 7 and 8 summarize results from several modifications to the benchmark specification. Table 7 shows results from changes in the estimation procedure (weighting the observations and alternative IV estimators); changes in the wage and unemployment variables (adjustments for changing demographics, industry mix, etc.); changes in the measure and treatment of productivity; and changes in the assumed timing of the variables. Table 8 summarizes results from specifications with more general dynamics. We discuss each of these in turn.

The first two rows of table 7 consider different estimators. The benchmark specification (IV with time and state effects, shown in the last column of table 6 and repeated at the top of table 7), used unweighted observations with observations for even months of the MORG used as instruments for observations corresponding to odd months. Specification (1) in table 7 reverses this and uses odd months as instruments for the even months. Specification (2) weights the state observations by state employment. In both specifications, this results in little change from the benchmark model.

Specifications (3)-(9) use different measures of wages and the unemployment rate. Specifications (3)-(6) use adjusted wage and employment data. The adjusted measures were computed by controlling for education, experience, race, gender, and industry (depending on the variable and specification) as detailed in the table notes, using the adjustment method described in section 7.1. The benchmark specification uses the sample average wages of all workers (as described in section 7.1) and specifications (7)-(9) consider alternative wage series (median wage of all workers, mean wage of full time workers, mean wage of hourly employees). The slope coefficient on the unemployment rate is essentially unaffected by these modifications to the benchmark specification.

Specifications (10)-(12) modify the way productivity enters the model. Specification (10) omits productivity from the analysis, so that the dependent variable in the regression is the log of real wage growth. Specification (11) adds productivity as a regressor, relaxing the constraint of a unit elasticity implicit in the benchmark model. Both of these changes to the benchmark specification lead to slightly larger estimates of the slope coefficient. The estimated productivity elasticity from specification (11) (not shown) is small (0.17 with a standard error of .13). There are several possible explanations for this. This result is consistent with substantial measurement error in the state productivity data. Additionally, even state productivity, precisely measured, contains short term fluctuations, and if it is trend productivity rather than annual productivity that is reflected in wages (as we have assumed in the macro specifications) then these estimates would be further biased towards zero. Finally, it might be that productivity only affects wage growth with a lag, an explanation that we investigate below.

Specification (12) uses an alternative measure of state productivity, the weighted average industry productivity growth that was described in section 7.2. This change produces a further steepening of the estimated Phillips curve.

The final two specifications in table 7 change the dating of productivity growth and then unemployment rate. Specification (13) uses replaces θ_{it+1} with θ_{it}, and specification (14) replaces u_{it} with u_{it+1}. Both changes result in a somewhat smaller estimated slope, suggesting that the timing convention in the benchmark specification is appropriate.

Changes in the dynamic specification. Table 8 considers changes in the dynamic specification of the model. Table 8a allows the lagged level of productivity adjusted real wages to enter the regression, relaxing the unit root constraint implied by the Phillips curve specification. We show results for both OLS and IV, specifications that include and exclude the productivity adjustments to real wages, and specifications that include the demographic and industry mix adjustments to wages. The OLS estimates show some evidence supporting mean reversion in real wages: the coefficients on lagged real wages range from -.09 to -.15 (implying AR roots of .85 to .91 for annual real wages) and appear to be statistically significant. However, measurement error in the MORG wage series imply that the OLS estimators have a negative bias. When IV is used to eliminate this bias, the estimated coefficients on lagged wages are much closer to zero and are statistically insignificant in the specifications that include productivity adjustments. (See Blanchard and Katz (1997) for similar estimates.)

Table 8b summarizes results for two specifications that allow distributed lags of wage growth and the unemployment rate in the model. These changes have little effect on the estimated slope of the Phillips curve, and the additional lagged variables are jointly insignificant in the regression.

Summary of the sensitivity analysis. The benchmark specification relates annual observations of productivity adjusted real wage growth to unemployment rates one year earlier together with time and state effects. The estimated slope is approximately –0.6

and there are no additional dynamics. The results in tables 7 and 8 are broadly consistent with this specification.

8.3 National TV-NAIRUs Estimated Using the State Data

Estimates of the national TV-NAIRU derived from the estimated time effects in the benchmark model are plotted in figure 7. Also shown are results from the specification that omits productivity and uses the real wage instead of unit labor cost as the dependent variables (specification (10) of table 7). These estimates were computed by the method described in section 6.2. The figure also plots the national unemployment rate and its univariate trend. The mean of the dependent variables in the two state regressions differ, so for comparison purposes the state estimates of the national TV-NAIRUs have been shifted so that they have the same mean as the national unemployment rate over the 1979-1997 period.

The estimated national TV-NAIRU based on the state unit labor cost regression is similar to the univariate trend in national unemployment, and thus is similar to the TV-NAIRUs estimated using the macro data. In contrast, the estimated national TV-NAIRU based on the state real wage regression falls only slightly in the 1990s. Mechanically, this arises because the real wage regressions implicitly introduce drift in the mean productivity growth rate into the NAIRU: the sharp increase in real wages in the late 1990s implies that the unemployment rate must have been well below the NAIRU during this period, if one neglects increases in the growth rate of productivity. Upon incorporating productivity into the dependent variable in the state panel regressions, the NAIRU falls substantially. This, then, is consistent with the conclusion from the analysis of the macro data that incorporating productivity reconciles the strong real wage growth of the 1990s with an estimate of a declining unemployment TV-NAIRU estimated in price regressions.

We conclude from these estimates that, despite substantial differences in the data sets, span, and periodicity, the state and macro evidence are mutually consistent. This sanguine conclusion must be tempered by a recognition that both the state estimates of the TV-NAIRUs are quite imprecise: the Kalman smoother estimate of the standard error on the decline in the state estimate of the TV-NAIRU from 1992 to 1997 using unit labor costs is 0.7 percentage points, and this standard error ignores estimation error. This imprecision should not be too surprising because the national estimates are based on smoothing the time series of estimated time effects that has only 20 annual observations.

9. State Evidence on Structural Sources of Shifts in the NAIRU

This section reports the results of state panel regressions that examine the stability of the Phillips curve over time and across regions and that include variables that represent possible structural factors that determine the NAIRU. Our conclusions from the state regressions are summarized at the end of this section.

9.1 Stability

The stability of the wage Phillips curves over time and across regions is investigated in table 9. There is no evidence that the slope of the Phillips has changed over time. This is shown in table 9 using productivity adjusted real wage growth; similar results, not reported in the table, were obtained using real wage growth without a productivity adjustment. This confirms Katz and Krueger's (1999) results using OLS that the state Phillips curve has been stable over time.

Interestingly, there is some evidence that the coefficient on the unemployment rate differs depending on the region of the country (where regions are defined to be the four Census regions). The Northeast and the West are estimated to have flatter Phillips curves than elsewhere. These regional interactions are marginally significant (the p-value is .07). Understanding whether there actually is regional variation in this slope, and if so why, is an interesting topic for future resource.

9.2 Demographics and Education

We now turn to regressions that investigate possible structural reasons that the NAIRU might change over time. The first such regressions examine the role of demographics and education, a theme recently emphasized by Shimer (1998).

Table 10 reports the results of regressions which include, either individually or together, the percent of high school dropouts, the percent of college graduates, the percent white in the work force, the percent female in the workforce, and the percent of the workforce aged between 25 and 54 years. These variables and the unemployment rate are measured in percentage points. The estimated coefficients are large, but so are their standard errors, and none of the demographic or education variables are statistically significant at the 5% level, either individually or jointly. For example, the coefficient on the percent of high school dropouts in the second column is –0.099, which implies that a one percentage point increase in the fraction of high school dropouts is associated with a decrease in the NAIRU of 0.15 percentage points (-.099/.642). However the standard error of this estimated effect is very large (0.23 percentage points) so that this specification produces a 95% confidence interval for the effect of a 1 percentage point increase in high school dropouts on the NAIRU that ranges from a decline of 0.6 percentage points to an increase of 0.3 percentage points. The large standard errors reflect the fact that, once state and time effects have been removed, there is only limited within-state variation in these slow moving demographic variables.

Lerman and Schmidt (1999) have claimed that the recent rise (and impending decline) in the share of prime-age workers, along with the continuing rise in the share of college-educated workers, are key factors in understanding recent (and future) changes in the labor market.[8] However, the timing of these demographic shifts do not coincide well with the downturn in the estimated NAIRU since 1992. In particular, the share of the workforce with a college degree increased steadily in both the 1980s and 1990s, which would suggest a steady decline in the NAIRU over the entire period. Similarly, the share of the workforce between the ages of 25 and 54 increased dramatically between 1979 and 1992, but has been flat or even declined since then. Thus, neither of these factors increased at a higher rate in the 90s, which is what would be needed to explain the sudden decline in the NAIRU after 1992. Despite the inability of these demographic shifts to explain recent changes in the NAIRU, it is worth noting that the point estimates imply

[8] Lerman and Schmidt (1999) also present some limited evidence suggesting that there is no relationship between the unemployment rate and wage growth in the late 1990s, which is at odds with the evidence we present in table 6. In particular, they report no relationship between growth in wages at the state level from 1995 (Q1) to 1998 (Q1) and a state's unemployment rate quartile in 1998 (Q1), based on three months of CPS data from 1995 and 1998. A number of aspects of the Lerman and Schmidt evidence are likely to bias their estimate toward finding no relationship. In particular, the small sample sizes from using only 3 months of data exacerbate the measurement error issues in the unemployment rate. More importantly, their focus on a single 3-year difference with unemployment measured at the end of the difference is at odds with the usual Phillips curve specification that focuses on short differences and lagged unemployment.

that the impending decline in the share of prime-age workers over the next twenty years (as the baby boomers retire) would exert upward pressure on the NAIRU. Thus, reconciling the state-level estimates of demographic effects on the NAIRU with the macro-level evidence in changes in the NAIRU is an important topic of future research.

9.3 Industry Characteristics and Temporary Help

Table 11 reports results for regressions including industry characteristics and the relative size of the temporary help industry in the state.

The results suggest that increases in the share of retail trade and services are associated with increases in the NAIRU, relative to manufacturing, but these effects are not statistically significant. Similarly, the point estimates suggest that increases in temporary help and self employment lead to declines in the NAIRU, but again, these estimated effects are not statistically significant.[9]

9.4 Government Policies

Table 12 examines the effect of state labor market policies on the NAIRU. These include the percent of the prime aged workforce on social security disability or SSI, the minimum wage, the growth of the minimum wage, and the unemployment insurance replacement rate.

None of the coefficients on these regressors is statistically significant at the 5% level in any of the specifications.

9.5 Summary of State Results

The finding that the unemployment rate significantly enters equations for either the change in labor share or real wage equations is highly robust to changes in specification, including lags, using different measures of wages, using demographically adjusted data, and controlling for a large number of possible structural determinants of the NAIRU. The coefficient is estimated to be approximately –0.6. This coefficient is stable over time, although there seem to be some intriguing but uninvestigated variations in this coefficient over different regions of the country.

In contrast, the state evidence on the determinants of the NAIRU is generally negative. None of the state labor market policy variables enter statistically significantly. Neither industry composition nor the size of the temporary help sector are statistically significant determinants of the NAIRU in the IV regressions. Of the demographic and education variables, there is some evidence that relatively more workers in the prime age work group contribute to reductions in the NAIRU, but this effect is estimated very imprecisely.

Despite the lack of statistical significance of these effects, it is worth checking whether the point estimates of the coefficients are consistent with these variables potentially having an economically substantial effect on the NAIRU, and in particular the evolution of the NAIRU through the 1990s. The point estimates associated with the demographic variables are, in fact, consistent with these variables having economically large effects, but the timing of these effects is inconsistent with their playing an important role in the fall in the NAIRU since 1992; rather, they contribute to a decline in the

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[9] Katz and Krueger (1999) find a statistically significant effect of temporary help on the NAIRU in Phillips curves estimated from state data. Their result appears to depend in an important way on the particulars of

NAIRU prior to 1992, but their contribution is estimated to have increased the national NAIRU since 1992.

The point estimates associated with the industry mix variables, including temporary help (table 11, last column) do point to a contribution that would lower the NAIRU by approximately half a percentage point from 1992 to 1997, but this effect is not statistically significant.

Overall, these state panel regressions fail to pinpoint any economic determinants of the TV-NAIRU. This accords with the macro evidence in Stock (1999) that education and demographic variables are inconsistent at the macro level with the trends in the NAIRU. Our finding contrasts somewhat with Katz and Krueger, who find some evidence that the rise of the temporary help industry has contributed to the fall in the national NAIRU (they estimate that temporary help has reduced the national TV-NAIRU by approximately 0.4 percentage points since 1990). Our specifications differ somewhat from theirs, however, and we find that the effect of temporary help is not robust.

10. Conclusions

We assess these results by returning to the three questions of the introduction.

First did the Phillips curve break down in the 1990s, or did it simply shift, with a new and evolving NAIRU? In both our macro and state analysis, we found abundant evidence of a stable relation both between both the change in price inflation and activity gaps of economic activity, and between unit labor costs and these activity gaps. These

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their specification and estimator (OLS).

two pieces of evidence are confirmatory and are particularly striking because the state panel estimates included time effects, thereby eliminating the variation in the data that drives the macro estimates. Moreover, in the macro analysis we found evidence that there was little intercept drift when the regressions were estimated as gaps; that is, when specified in gaps, neither the price nor the wage Phillips curve has shifted in the 1990s. Thus, this evidence falls squarely on the side of the "Phillips curve is alive and well but..." theories.

Second, given this finding, why has the price Phillips curve shifted in? The macro analysis suggests that the answer is *not* that we have had a particularly fortunate string of supply shocks; we did in the mid-1990s, but they were subsequently reversed. In addition, both the macro and state evidence suggests that an autonomous shift in wage or price setting behavior by firms also is not an important part of the inflation-unemployment story of the 1990s: had changes in price or wage setting behavior been the reason for the apparent decline in the NAIRU, the NAIRU and the univariate trend in unemployment would differ, but they do not. This finding is reinforced by the limited role we found for industry mix variables in the state panel data analysis. This suggests that labor market factors, such as demographics, the rise of the temporary help industry, or labor market policies must be the source of the changes in the NAIRU. Curiously, however, our results do not point in this direction. The macro estimates of the change in the NAIRU from 1992 – 2000 using the demographically adjusted unemployment rate are virtually the same as using the total unemployment rate. Similarly, our attempts to identify structural determinants of the NAIRU using the state data were disappointing.

Several effects pointed in the right direction, but the state data did not provide precise estimates of these effects.

Third, can the labor productivity gains of the 1990s explain the apparently aberrant recent behavior of real wages in Figure 1b? Yes: the TV-NAIRUs estimated both on the macro and state data are the same whether the change in inflation or real wages less productivity are the dependent variable, and differ sharply during the 1990s only when the productivity component is omitted from wages.

The simplest summary of these results is that, once one accounts for the univariate trends in the unemployment rate and in productivity, the1990s present no price or wage puzzles. Thus, the task is to explain trend movements in productivity and in unemployment. In our framework, trend unemployment and the NAIRU are identified separately, but as it happens these two series track each other very closely. Because the long run trend components of the rates of inflation and unemployment are essentially unrelated in the postwar U.S. data (Stock and Watson [1999a]), we are skeptical of explanations that link the two such as those of Akerlof, Dickens and Perry (1996) or Taylor (2000).

It is potentially more promising to consider explanations that directly link the trend components of productivity growth and the unemployment rate. These univariate trends, which are plotted in figure 8a, show a striking and intriguing negative correlation. The recent coincident increase in productivity growth and decrease in the unemployment rate recalls a similar pattern in the early 1960s. This pattern reversed itself in the 1970's, when trend productivity growth fell and the trend unemployment rate increased. The close relationship between the series also can be seen in the scatterplot of the series shown in figure 8b. Of course, the figure must be viewed with caution since unrelated trends can spuriously appear to be correlated. Indeed, it seems reasonable to think of figure 8b as four data observations – 1960-67, 1967-1980, 1980-1993 and 1993-2000 – and it is difficult to be sure of a correlation with only four observations. Yet, we find the empirical results strong enough, and the question important enough, to warrant further attention by both macro and labor economists.

Data Appendix

This appendix documents some features of the macroeconomic data used in section 2-5. All series are from DRI Basic Economics Database (formerly Citibase). Quarterly averages were used for variables that were available monthly Listed below is the database mnemonic, a brief series description, and the series abbreviation used in tables 2-4:

Price Series

GDPD	Gross Domestic Product: Implicit Price Deflator (GDP Def)
GMDC	Pce,Implicit price deflator (PCE Def)
PUNEW	CPI-U All Items CPI (CPI)
LBGDPU	Nonfarm Business: Implicit Price Deflator (NFB Def)

Wage Series

LBPUR	Compensation Per Hour,Employees: Nonfarm Business (Comp/Hr)
LEH	Avg Hr Earnings Of Prod Wkrs: Total Private Nonagric (AHE PW)
LCP	Employment Cost Index (Compensation): Priv. Ind. Wks (ECC-C)
LWI	Employment Cost Index (Wage & Salar.):Privt Ind.Wks (ECC-WS)

Real Activity Variables

LHUR	Unemployment Rate: All Workers, 16 Years & Over (Civ. Unemp)
HSBR	Housing Authorized: Total New Private Housing Units (Bldg. Perm.)
IPXMCA	Capacity Util Rate: Manufacturing (Cap. Util.)

Productivity

LBOUTU	Output Per Hour All Persons: Nonfarm Business
LOUTM	Output Per Hour Of All Persons, Index - Manufacturing

Other Variables

PUXX	CPI-U: All Items Less Food And Energy
EXVUS	Foreign Exchange Value Of The Us Dollar

Constructed Variables

Exchange Rate: EXVUS from 1973:1 through 2000:6. From 1959:1-1972:12 this is a trade-weighted average of the $ exchange rates for France, Germany, Italy, Japan and the United Kingdom descrideb in Stock and Watson (1989). The two series were linked in 1973:1.

Relative Price of Food and Energy: $\ln(punenw_t/punew_{t-1}) - \ln(puxx_t/puxx_{t-1})$.

Wage a Price Control Variable: This variable takes on the values 0.8 from 1971:3-1972:3, -0.4 from 1974:2-1974:2, -1.6 from 1974:3-1974:4, -0.4 from 1975:1-1975:1, and 0 for all other dates. It is taken from Gordon (1982).

The specifications that included “Supply Shocks” included 4 lags of the relative price of food and energy, 4 lags of the log-difference of the exchange rate, and the wage and price control variable.

Demographically Adjusted Unemployment Rate: See text.

Bias Corrections for the Inflation Series: Price inflation was adjusted for the improvements in measurement implemented by the Bureau of Labor Statistics, as suggested in Gordon (1998). The adjustments were taken from the Economic Report of the President (1998 page 80, Table 2.4). The values used form the CPI and PCE are: -.12 from 1995:1 to 1995:4, -.22 from 1996:1 to 1996:4, -.28 from 1997:1 to 1997:4, -.49 from 1998:1 to 1998:4, and -.69 from 1999:1 to 2000:2. The values for the GDP deflator are -.06 from 1996:1 to 1996:4, -.06 from 1997:1 to 1997:4, -.08 from 1998:1 to 1998:4 and -.20 from 1999:1 to 2000:2.

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Table 1
Descriptive Statistics for Trend Characteristics of the Data

Series	Sample Mean				95% CI for the largest AR root
	60:1-69:4	70:1-79:4	80:1 89:4	90:1-99:4	
Price Inflation	2.47	6.50	4.46	2.23	0.90 to 1.02
Nominal Wage Growth Rate	4.95	8.05	5.36	3.72	0.91 to 1.02
Nominal Wage-Productivity Growth Rate	2.22	6.09	3.94	1.70	0.81 to 1.00
Real Wage[1] Growth Rate	2.48	1.55	0.90	1.49	< 0.93
Real Wage[2] Growth Rate	2.86	1.81	1.15	1.71	< 0.89
Real Wage[1]-Productivity Growth Rate	-0.25	-0.40	-0.52	-0.52	< 0.77
Real Wage[2]-Productivity Growth Rate	0.14	-0.15	-0.27	-0.30	< 0.77
Productivity Growth Rate	2.72	1.96	1.42	2.02	< 0.80
Real Wage[1]/Productivity (Log)	-.029	-.067	-.080	-.138	0.97 to 1.03
Real Wage[2]/Productivity (Log)	-.014	-.010	-.012	-.052	0.91 to 1.02
Unemployment Rate	4.78	6.21	7.27	5.76	0.89 to 1.02
Dem. Adj. Unemp. Rate	5.04	6.06	7.26	6.11	0.86 to 1.01
Building Permits (Log)	7.07	7.31	7.24	7.17	< 0.89
Capacity Utilization Rate	85.0	81.6	79.0	80.9	< 0.93

Notes: Columns 2-5 show the sample means of the series listed in the first column over the sample period indicated in the second row. The final column shows the 95 confidence for the largest root in a univariate AR(6) model (including the constant). The sample period for the regression was 1960:1-2000:2. The confidence interval was computed using the approximation developed in Stock (1991), for highly persistent series. Several of the series were not very persistent, and Stock's method could only be used to compute an upper confidence bound. Real Wage[1] uses price inflation computed from the GDP deflator, and Real Wage[2] uses price inflation computed from the price deflator for the non-farm business sector.

Table 2
Phillips Curve Estimates from Macroeconomic Data
Price Inflation Equation

$$\Delta\pi_{t+1} = \beta_\pi(u_t - u_t^N) + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi x}(L)\Delta u_t + \gamma_\pi Z_t + v_{\pi t+1}$$

	Civilian Unemployment Rate	Demographically Adjusted Unemployment Rate	Capacity Utilization	Building Permits
Phillips Curve Slope (SE) [Stability P-value]	-0.28 (0.10) [0.06]	-0.26 (0.09) [0.13]	0.09 (0.03) [0.02]	2.20 (0.44) [0.17]
Trend Values				
1970	4.33	4.39	85.51	7.27
1980	7.79	7.55	78.74	7.23
1990	6.40	6.66	80.84	7.18
2000	4.48	4.83	81.02	7.31
Change 1992-2000	-1.60	-1.59	-0.57	0.17
NAI Trend Values (SE)				
1970	4.60 (0.39)	4.64 (0.42)	84.93 (1.22)	7.23 (0.05)
1980	7.73 (0.38)	7.51 (0.40)	79.06 (1.16)	7.25 (0.05)
1990	6.39 (0.39)	6.66 (0.42)	80.82 (1.22)	7.18 (0.05)
2000	4.52 (0.52)	4.87 (0.55)	80.61 (1.59)	7.33 (0.07)
Change 1992-2000	-1.59 (0.45)	-1.58 (0.46)	-0.89 (1.30)	0.18 (0.06)
SER	0.92	0.93	0.94	0.91
TVP Std. Error (90% Conf. Int.)	0.024 (0.000 -0.108)	0.022 (0.000 -0.105)	0.022 (0.000 -0.106)	0.027 (0.000 -0.114)

Notes: Results for the first column use the civilian unemployment rate as u in the estimated equation. The row labeled *Phillips Curve Slope* shows the estimates of β_π, with the standard error in parentheses, and the p-value of the QLR stability test in brackets. *Trend Values* are the (univariate) low-pass estimates of trend unemployment rate, and *NAI Trend Values* are the estimated values of the NAIRU computed using the Kalman smoother, as described in the text. *SER* is the standard error of the regression, and the *TVP Std. Error* is the median unbiased estimate of the standard deviation of the change in the equation's constant term. The equation was estimated using 4 lags of $\Delta\pi_t$, two lags of Δu_t; the vector Z contained Gordon's (1982) wage and price control variable, two lags of the relative price of food and energy and two lags of the exchange rate. The sample period is 1960:1-2000:2. Results in the remaining columns replace u with the demographically adjusted unemployment rate, capacity utilization and building permits.

Table 3
Alternative Phillips Curve Estimates from Macroeconomic Data
Price Inflation Equation

$$\Delta\pi_{t+1} = \beta_\pi(u_t\text{-}u_t^N) + \alpha_{\pi\pi}(L)\Delta\pi_t + \alpha_{\pi x}(L)\Delta u_t + \alpha_{\omega\omega}(L)(\omega_t - \theta^*_{t-1} - \pi_{t\text{-}1}) + \alpha_{\omega\omega}(L)\Delta\omega_t + \gamma_\pi Z_t + \nu_{\pi t+1}$$

Price	Activity	Np Na Ng Nr Nx Ne Nw Nm	PC Slope	SER	TVPSE	Δ NAITV: median ub	Δ Intercept: median ub	Δ NAITV: 5%	ΔIntercept: 5%
A. Baseline Specification (Table 1)									
GDP Def	Civ. Unemp.	4 2 1 2 2 0 0 0	-0.28 (0.10) [0.06]	0.92	0.024	-1.59 (0.45)	0.00 (0.13)	-1.59 (0.68)	0.00 (0.19)
GDP Def	Dem Adj. UR	4 2 1 2 2 0 0 0	-0.26 (0.09) [0.13]	0.93	0.022	-1.58 (0.46)	0.00 (0.12)	-1.58 (0.75)	0.00 (0.19)
GDP Def	Cap. Util.	4 2 1 2 2 0 0 0	0.09 (0.03) [0.02]	0.94	0.022	-0.89 (1.30)	0.03 (0.12)	-1.30 (2.14)	0.07 (0.19)
GDP Def	Bldg. Perm.	4 2 1 2 2 0 0 0	2.20 (0.44) [0.17]	0.91	0.027	0.18 (0.06)	-0.02 (0.14)	0.19 (0.09)	-0.04 (0.19)
B. Different Price Indices									
PCE Def	Civ. Unemp.	4 2 1 2 2 0 0 0	-0.28 (0.11) [0.21]	1.08	0.015	-1.59 (0.29)	0.00 (0.08)	-1.54 (0.70)	0.02 (0.20)
PCE Def	Dem Adj. UR	4 2 1 2 2 0 0 0	-0.27 (0.11) [0.29]	1.09	0.010	-1.59 (0.21)	0.00 (0.06)	-1.52 (0.74)	0.02 (0.20)
PCE Def	Cap. Util.	4 2 1 2 2 0 0 0	0.10 (0.03) [0.49]	1.07	0.016	-0.68 (0.85)	0.01 (0.09)	-1.19 (1.95)	0.06 (0.20)
PCE Def	Bldg. Perm.	4 2 1 2 2 0 0 0	2.05 (0.55) [0.18]	1.08	0.016	0.18 (0.04)	-0.01 (0.09)	0.18 (0.10)	-0.02 (0.20)
CPI	Civ. Unemp.	4 2 1 2 2 0 0 0	-0.39 (0.14) [0.16]	1.34	0.000	-1.60 (.)	0.00 (0.00)	-1.57 (0.53)	0.01 (0.20)
CPI	Dem Adj. UR	4 2 1 2 2 0 0 0	-0.37 (0.14) [0.19]	1.35	0.000	-1.59 (.)	0.00 (0.00)	-1.56 (0.55)	0.01 (0.20)
CPI	Cap. Util.	4 2 1 2 2 0 0 0	0.15 (0.04) [0.19]	1.34	0.000	-0.57 (0.00)	0.00 (0.00)	-1.04 (1.40)	0.07 (0.20)
CPI	Bldg. Perm.	4 2 1 2 2 0 0 0	3.63 (0.71) [0.05]	1.37	0.028	0.18 (0.04)	-0.01 (0.15)	0.18 (0.06)	-0.03 (0.20)
C. Adding lags of wage inflation and error-correction term									
GDP Def	Civ. Unemp.	4 2 1 2 2 1 4 0	-0.25 (0.10) [0.07]	0.91	0.025	-1.63 (0.51)	-0.01 (0.13)	-1.70 (0.76)	-0.03 (0.19)
GDP Def	Dem Adj. UR	4 2 1 2 2 1 4 0	-0.23 (0.10) [0.16]	0.92	0.023	-1.62 (0.53)	-0.01 (0.12)	-1.70 (0.84)	-0.02 (0.19)
GDP Def	Cap. Util.	4 2 1 2 2 1 4 0	0.09 (0.03) [0.02]	0.94	0.023	-0.81 (1.41)	0.02 (0.12)	-0.99 (2.21)	0.04 (0.19)
GDP Def	Bldg. Perm.	4 2 1 2 2 1 4 0	2.07 (0.44) [0.21]	0.91	0.029	0.19 (0.07)	-0.03 (0.15)	0.20 (0.09)	-0.06 (0.19)
D. Increasing lag length									
GDP Def	Civ. Unemp.	8 4 1 2 2 0 0 0	-0.35 (0.12) [0.34]	0.89	0.050 *	-1.65 (0.65)	-0.02 (0.23)	-1.62 (0.55)	-0.01 (0.19)
GDP Def	Dem Adj. UR	8 4 1 2 2 0 0 0	-0.31 (0.12) [0.27]	0.91	0.047 *	-1.64 (0.71)	-0.02 (0.22)	-1.61 (0.61)	-0.01 (0.19)
GDP Def	Cap. Util.	8 4 1 2 2 0 0 0	0.11 (0.03) [0.01]	0.94	0.041	-1.25 (1.90)	0.07 (0.20)	-1.21 (1.83)	0.07 (0.19)
GDP Def	Bldg. Perm.	8 4 1 2 2 0 0 0	2.30 (0.50) [0.24]	0.92	0.041	0.19 (0.09)	-0.03 (0.20)	0.19 (0.08)	-0.03 (0.19)
GDP Def	Civ. Unemp.	8 4 1 4 4 0 0 0	-0.34 (0.12) [0.41]	0.89	0.043 *	-1.62 (0.59)	-0.01 (0.20)	-1.61 (0.55)	-0.00 (0.19)
GDP Def	Dem Adj. UR	8 4 1 4 4 0 0 0	-0.31 (0.12) [0.32]	0.91	0.040	-1.60 (0.63)	-0.00 (0.19)	-1.60 (0.62)	-0.00 (0.19)
GDP Def	Cap. Util.	8 4 1 4 4 0 0 0	0.11 (0.03) [0.01]	0.95	0.035	-1.14 (1.65)	0.06 (0.18)	-1.23 (1.81)	0.07 (0.19)
GDP Def	Bldg. Perm.	8 4 1 4 4 0 0 0	2.26 (0.51) [0.38]	0.92	0.042	0.19 (0.09)	-0.04 (0.20)	0.19 (0.08)	-0.03 (0.19)
E. Eliminating RPFE ExRates and W&P Control Variables									
GDP Def	Civ. Unemp.	4 2 0 0 0 0 0 0	-0.37 (0.10) [0.08]	1.00	0.047	-1.53 (0.61)	0.02 (0.22)	-1.54 (0.53)	0.02 (0.19)
GDP Def	Dem Adj. UR	4 2 0 0 0 0 0 0	-0.34 (0.10) [0.17]	1.02	0.047	-1.51 (0.66)	0.03 (0.23)	-1.53 (0.57)	0.02 (0.20)
GDP Def	Cap. Util.	4 2 0 0 0 0 0 0	0.11 (0.03) [0.05]	1.02	0.049 *	-1.46 (2.06)	0.10 (0.23)	-1.23 (1.75)	0.07 (0.20)
GDP Def	Bldg. Perm.	4 2 0 0 0 0 0 0	1.78 (0.44) [0.23]	1.03	0.031	0.17 (0.09)	-0.00 (0.16)	0.17 (0.11)	-0.00 (0.20)
F. Adding Markup Variable									
GDP Def	Civ. Unemp.	4 2 1 2 2 0 0 2	-0.27 (0.10) [0.09]	0.91	0.035	-1.42 (0.65)	0.05 (0.17)	-1.40 (0.71)	0.05 (0.19)
GDP Def	Dem Adj. UR	4 2 1 2 2 0 0 2	-0.24 (0.09) [0.19]	0.92	0.035	-1.39 (0.73)	0.05 (0.18)	-1.37 (0.80)	0.05 (0.19)
GDP Def	Cap. Util.	4 2 1 2 2 0 0 2	0.09 (0.03) [0.02]	0.93	0.023	-0.99 (1.45)	0.04 (0.12)	-1.40 (2.25)	0.07 (0.19)

GDP Def	Bldg. Perm.	4 2 1 2 2 0 0 2	2.09 (0.44) [0.27]	0.90	0.025	0.16 (0.06)	0.02 (0.13)	0.16 (0.09)	0.03 (0.19)
GDP Def	Civ. Unemp.	8 4 1 2 2 0 0 2	-0.32 (0.12) [0.33]	0.89	0.043 *	-1.43 (0.63)	0.05 (0.20)	-1.44 (0.59)	0.05 (0.19)
GDP Def	Dem Adj. UR	8 4 1 2 2 0 0 2	-0.28 (0.12) [0.27]	0.90	0.040	-1.41 (0.68)	0.05 (0.19)	-1.41 (0.68)	0.05 (0.19)
GDP Def	Cap. Util.	8 4 1 2 2 0 0 2	0.10 (0.03) [0.01]	0.94	0.036	-1.21 (1.79)	0.06 (0.18)	-1.29 (1.94)	0.07 (0.19)
GDP Def	Bldg. Perm.	8 4 1 2 2 0 0 2	2.20 (0.50) [0.29]	0.91	0.031	0.16 (0.07)	0.03 (0.16)	0.16 (0.09)	0.03 (0.19)

Notes: This table contains alternative estimates of the price Phillips Curve equation and the TV NAIRU. The first column shows the price series used to construct π, and the second column shows the activity variable used for u. The next columns shows a set of parameters that described the specification: Np = number of lags of inflation, Na = number of lags of activity variable, Ng is a binary variable indicating inclusion(1)/exclusion(0) of Wage and Price Variable (Gordon (1982)), Nr = number of lags of the relative price of food and energy, Nx = number of lags of exchange rates, Ne is a binary variable indicating inclusion(1)/exclusion(0) of the wage/price/productivity error correction term ($\omega_t - \theta^*_{t-1} - \pi_{t-1}$), Nw = number of lags of $\Delta\omega$, and Nm=number of lags of markup variable described in the text. The next three columns are described in the notes to Table 1. An asterisk in the column labeled TVPSE indicates that the estimated TVPSE is significantly different from 0 at the 5% level. The columns labeled Δ NAITV show the change in the NAIRU (or the NAI trend value) from 1992:1-2000:1, and the columns labeled Δ Intercept show the implied in the equation's constant term over the same period. These are presented for two value of the standard error of the change in the constant: the median unbiased estimate (shown in column (6)), and a value of .039 (which implies a standard deviation of the change in the constant of 5% over the sample period.) The sample period is 1960:1-2000:1 for all estimated equations.

Table 4
Phillips Curve Estimates from Macroeconomic Data
Wage Inflation Equation

$$\omega_{t+1}-\theta_t^*-\pi_t = \beta_\omega(u_t-u_t^N) + \alpha_{\omega\pi}(L)\Delta\pi_t + \alpha_{\omega\omega}(L)(\omega_t-\theta_{t-1}^*-\pi_{t-1}) + \alpha_{\omega u}(L)\Delta u_t + v_{\omega t+1}$$

	Civilian Unemployment Rate	**Demographically Adjusted Unemployment Rate**	**Capacity Utilization**	**Building Permits**
Phillips Curve Slope (SE) [Stability P-value]	-0.42 (0.19) [0.12]	-0.39 (0.18) [0.12]	0.11 (0.05) [0.29]	2.00 (0.78) [0.99]
Trend Values				
1970	4.33	4.39	85.51	7.27
1980	7.79	7.55	78.74	7.23
1990	6.40	6.66	80.84	7.18
2000	4.48	4.83	81.02	7.31
Change 1992-2000	-1.60	-1.59	-0.57	0.17
NAI Trend Values				
1970	3.74 (0.47)	3.73 (0.51)	88.50 (1.50)	7.41 (0.10)
1980	6.95 (0.44)	6.63 (0.48)	82.06 (1.43)	7.41 (0.09)
1990	5.33 (0.47)	5.49 (0.51)	84.42 (1.50)	7.41 (0.10)
2000	3.48 (0.60)	3.72 (0.65)	84.55 (1.70)	7.54 (0.13)
Change 1992-2000	-1.52 (0.46)	-1.51 (0.49)	-0.66 (0.89)	0.16 (0.10)
SER	1.81	1.81	1.82	1.81
TVP Std. Error (90% Conf. Int.)	0.036 (0.000 -0.188)	0.035 (0.000 -0.187)	0.017 (0.000 -0.162)	0.037 (0.000 -0.190)

Notes: The equation was estimated using 4 lags of $\Delta\pi_t$, 4 lags of $(\omega_t-\theta_{t-1}^*-\pi_{t-1})$ and two lags of Δu_t. See notes to table 1 for a description of the table entries.

Table 5
Alternative Phillips Curve Estimates from Macroeconomic Data
Wage Inflation Equation

$$\omega_{t+1} - \theta_t^* - \pi_t = \beta_\omega(u_t - u_t^N) + \alpha_{\omega\pi}(L)\Delta\pi_t + \alpha_{\omega\omega}(L)(\omega_t - \theta_{t-1}^* - \pi_{t-1}) + \alpha_{\omega u}(L)\Delta u_t + v_{\omega t+1}$$

Wage	Price	Activity	Nw Na Np Pr	PC Slope	SER	TVPSE	Δ NAITV: median ub	Δ Intercept: median ub	Δ NAITV: 5%	Δ Intercept: 5%
A. Baseline Specification (Table 3)										
Comp/Hr	GDP Def	Civ. Unemp.	4 2 4 2	-0.42 (0.19) [0.12]	1.81	0.036	-1.52 (0.46)	0.03 (0.19)	-1.50 (0.50)	0.04 (0.21)
Comp/Hr	GDP Def	Dem Adj. UR	4 2 4 2	-0.39 (0.18) [0.12]	1.81	0.035	-1.51 (0.49)	0.03 (0.19)	-1.49 (0.55)	0.04 (0.21)
Comp/Hr	GDP Def	Cap. Util.	4 2 4 2	0.11 (0.05) [0.29]	1.82	0.017	-0.66 (0.89)	0.01 (0.10)	-1.12 (1.93)	0.06 (0.21)
Comp/Hr	GDP Def	Bldg. Perm.	4 2 4 2	2.00 (0.78) [0.99]	1.81	0.037	0.16 (0.10)	0.03 (0.20)	0.16 (0.11)	0.03 (0.21)
B. Alternative productivity trends										
Comp/Hr	GDP Def	Civ. Unemp.	4 2 4 1	-0.42 (0.19) [0.15]	1.85	0.103 *	-0.79 (1.12)	0.34 (0.47)	-1.43 (0.50)	0.07 (0.21)
Comp/Hr	GDP Def	Dem Adj. UR	4 2 4 1	-0.38 (0.19) [0.14]	1.85	0.102 *	-0.70 (1.23)	0.34 (0.47)	-1.41 (0.56)	0.07 (0.21)
Comp/Hr	GDP Def	Cap. Util.	4 2 4 1	0.12 (0.05) [0.56]	1.87	0.092 *	-3.74 (3.68)	0.37 (0.43)	-1.33 (1.79)	0.09 (0.21)
Comp/Hr	GDP Def	Bldg. Perm.	4 2 4 1	1.78 (0.81) [0.89]	1.87	0.078	0.04 (0.21)	0.23 (0.38)	0.14 (0.12)	0.07 (0.21)
Comp/Hr	GDP Def	Civ. Unemp.	4 2 4 3	-0.40 (0.19) [0.37]	1.80	0.060	-1.61 (0.78)	-0.00 (0.31)	-1.63 (0.53)	-0.01 (0.21)
Comp/Hr	GDP Def	Dem Adj. UR	4 2 4 3	-0.36 (0.18) [0.36]	1.80	0.059	-1.60 (0.84)	-0.00 (0.30)	-1.62 (0.58)	-0.01 (0.21)
Comp/Hr	GDP Def	Cap. Util.	4 2 4 3	0.11 (0.05) [0.22]	1.81	0.049	-0.75 (2.34)	0.02 (0.25)	-0.64 (1.94)	0.01 (0.21)
Comp/Hr	GDP Def	Bldg. Perm.	4 2 4 3	1.82 (0.78) [0.71]	1.81	0.062	0.18 (0.17)	-0.02 (0.32)	0.18 (0.12)	-0.02 (0.21)
C. Alternative price indices										
Comp/Hr	NFB Def	Civ. Unemp.	4 2 4 2	-0.35 (0.19) [0.34]	1.87	0.036	-1.59 (0.56)	0.00 (0.19)	-1.58 (0.61)	0.01 (0.21)
Comp/Hr	NFB Def	Dem Adj. UR	4 2 4 2	-0.31 (0.18) [0.33]	1.87	0.029	-1.59 (0.50)	-0.00 (0.16)	-1.57 (0.67)	0.01 (0.21)
Comp/Hr	NFB Def	Cap. Util.	4 2 4 2	0.11 (0.05) [0.41]	1.88	0.018	-0.61 (0.94)	0.00 (0.10)	-0.87 (2.00)	0.03 (0.21)
Comp/Hr	NFB Def	Bldg. Perm.	4 2 4 2	2.90 (0.83) [0.78]	1.84	0.035	0.18 (0.07)	-0.01 (0.19)	0.18 (0.07)	-0.01 (0.21)
Comp/Hr	PCE Def	Civ. Unemp.	4 2 4 2	-0.28 (0.19) [0.17]	1.83	0.102 *	-0.92 (1.64)	0.19 (0.46)	-1.52 (0.74)	0.02 (0.21)
Comp/Hr	PCE Def	Dem Adj. UR	4 2 4 2	-0.25 (0.18) [0.16]	1.84	0.101 *	-0.83 (1.82)	0.19 (0.46)	-1.50 (0.84)	0.02 (0.21)
Comp/Hr	PCE Def	Cap. Util.	4 2 4 2	0.08 (0.05) [0.52]	1.84	0.089 *	-3.47 (5.43)	0.22 (0.42)	-1.09 (2.73)	0.04 (0.21)
Comp/Hr	PCE Def	Bldg. Perm.	4 2 4 2	1.68 (0.83) [0.89]	1.83	0.103 *	0.08 (0.28)	0.17 (0.47)	0.17 (0.13)	0.01 (0.21)
Comp/Hr	CPI	Civ. Unemp.	4 2 4 2	-0.17 (0.20) [0.13]	1.85	0.098 *	-0.86 (2.59)	0.13 (0.45)	-1.53 (1.21)	0.01 (0.21)
Comp/Hr	CPI	Dem Adj. UR	4 2 4 2	-0.15 (0.19) [0.12]	1.85	0.095 *	-0.78 (2.97)	0.12 (0.44)	-1.51 (1.41)	0.01 (0.21)
Comp/Hr	CPI	Cap. Util.	4 2 4 2	0.06 (0.06) [0.71]	1.86	0.085	-3.27 (6.83)	0.16 (0.41)	-1.09 (3.54)	0.03 (0.21)
Comp/Hr	CPI	Bldg. Perm.	4 2 4 2	2.04 (0.87) [0.78]	1.83	0.109 *	0.13 (0.24)	0.08 (0.49)	0.17 (0.10)	-0.00 (0.21)
D. Alternative wage indices										
AHE PW	GDP Def	Civ. Unemp.	4 2 4 5	-0.15 (0.12) [0.55]	1.12	0.077 *	-1.36 (2.20)	0.04 (0.33)	-1.47 (1.32)	0.02 (0.20)
AHE PW	GDP Def	Dem Adj. UR	4 2 4 5	-0.14 (0.12) [0.48]	1.13	0.078 *	-1.32 (2.33)	0.04 (0.33)	-1.45 (1.40)	0.02 (0.20)
AHE PW	GDP Def	Cap. Util.	4 2 4 5	0.04 (0.03) [0.35]	1.11	0.062 *	-1.86 (6.91)	0.05 (0.28)	-1.31 (4.86)	0.03 (0.20)
AHE PW	GDP Def	Bldg. Perm.	4 2 4 5	1.06 (0.55) [0.71]	1.11	0.087 *	0.19 (0.33)	-0.01 (0.35)	0.18 (0.19)	-0.01 (0.20)
Comp/Hr Man	GDP Def	Civ. Unemp.	4 2 4 5	-0.49 (0.21) [0.45]	2.02	0.145 *	-1.76 (1.23)	-0.08 (0.61)	-1.72 (0.43)	-0.06 (0.21)
Comp/Hr Man	GDP Def	Dem Adj. UR	4 2 4 5	-0.47 (0.21) [0.45]	2.02	0.142 *	-1.76 (1.29)	-0.08 (0.60)	-1.72 (0.45)	-0.06 (0.21)
Comp/Hr Man	GDP Def	Cap. Util.	4 2 4 5	0.13 (0.06) [0.43]	2.04	0.139 *	-0.96 (4.61)	0.05 (0.60)	-0.24 (1.64)	-0.04 (0.21)
Comp/Hr Man	GDP Def	Bldg. Perm.	4 2 4 5	0.97 (0.92) [0.87]	2.06	0.148 *	0.18 (0.64)	-0.00 (0.62)	0.23 (0.22)	-0.05 (0.21)
ECC-C	GDP Def	Civ. Unemp.	4 2 4 2	-0.13 (0.11) [0.52]	0.58	0.023	-1.65 (0.86)	-0.01 (0.11)	-1.48 (1.27)	0.02 (0.17)

ECC-C	GDP Def	Dem Adj. UR	4 2 4 2	-0.12 (0.10) [0.56]	0.58	0.026	-1.64 (1.06)	-0.01 (0.13)	-1.48 (1.42)	0.01 (0.17)
ECC-C	GDP Def	Cap. Util.	4 2 4 2	0.03 (0.04) [0.01]	0.58	0.026	-1.55 (4.32)	0.03 (0.13)	-3.15 (5.83)	0.08 (0.17)
ECC-C	GDP Def	Bldg. Perm.	4 2 4 2	0.97 (0.55) [0.74]	0.57	0.014	0.18 (0.08)	-0.01 (0.08)	0.16 (0.17)	0.01 (0.17)
ECC-WS	GDP Def	Civ. Unemp.	4 2 4 2	-0.06 (0.12) [0.14]	0.76	0.108 *	5.46 (6.12)	0.39 (0.34)	1.64 (3.31)	0.18 (0.18)
ECC-WS	GDP Def	Dem Adj. UR	4 2 4 2	-0.06 (0.12) [0.20]	0.75	0.106 *	4.58 (5.29)	0.39 (0.34)	1.27 (2.88)	0.18 (0.18)
ECC-WS	GDP Def	Cap. Util.	4 2 4 2	0.03 (0.05) [0.85]	0.76	0.088 *	-10.47 (8.95)	0.34 (0.31)	-5.56 (5.37)	0.17 (0.18)
ECC-WS	GDP Def	Bldg. Perm.	4 2 4 2	2.19 (0.72) [0.14]	0.71	0.116 *	-0.02 (0.16)	0.43 (0.34)	0.07 (0.08)	0.22 (0.18)
E. Increasing lag length										
Comp/Hr	GDP Def	Civ. Unemp.	8 4 8 2	-0.49 (0.24) [0.06]	1.79	0.058	-1.37 (0.60)	0.11 (0.29)	-1.49 (0.43)	0.05 (0.21)
Comp/Hr	GDP Def	Dem Adj. UR	8 4 8 2	-0.45 (0.24) [0.07]	1.81	0.055	-1.36 (0.64)	0.10 (0.29)	-1.47 (0.47)	0.05 (0.21)
Comp/Hr	GDP Def	Cap. Util.	8 4 8 2	0.12 (0.07) [0.32]	1.80	0.034	-1.00 (1.50)	0.05 (0.19)	-1.15 (1.71)	0.07 (0.21)
Comp/Hr	GDP Def	Bldg. Perm.	8 4 8 2	2.46 (0.92) [0.76]	1.82	0.034	0.16 (0.08)	0.03 (0.18)	0.16 (0.09)	0.04 (0.21)
F. Eliminating lags of price inflation										
Comp/Hr	GDP Def	Civ. Unemp.	4 2 0 2	-0.12 (0.17) [0.02]	1.93	0.000	-1.60 (0.00)	0.00 (0.00)	-1.25 (1.74)	0.04 (0.21)
Comp/Hr	GDP Def	Dem Adj. UR	4 2 0 2	-0.09 (0.17) [0.02]	1.93	0.000	-1.59 (0.00)	0.00 (0.00)	-1.10 (2.48)	0.04 (0.21)
Comp/Hr	GDP Def	Cap. Util.	4 2 0 2	0.01 (0.05) [0.23]	1.93	0.000	-0.57 (0.00)	0.00 (0.00)	-5.21 (21.39)	0.05 (0.21)
Comp/Hr	GDP Def	Bldg. Perm.	4 2 0 2	1.05 (0.78) [0.94]	1.91	0.000	0.17 (0.00)	0.00 (0.00)	0.14 (0.20)	0.03 (0.21)

Notes: Notes: This table contains alternative estimates of the wage Phillips Curve equation and the TV NAIRU. The first column shows the wage series used to construct ω, the next column shows price series used to construct π and the third column shows the activity variable used for u. The next columns shows a set of parameters that described the specification: Nw= number of lags of real wages, Np = number of lags of inflation, Na = number of lags of activity variable, Pr = trend estimate of productivity growth (1=Average value of NFB productivity growth, 1960-2000; 2=low-pass filter of NFB productivity growth using I(0) AR extrapolation; 3=low-pass filter of NFB productivity growth using I(1) AR extrapolation; 5=2=low-pass filter of manufacturing productivity growth using I(0) AR extrapolation). The remaining columns are described in the notes to Table 2. The sample period is 1960:1-2000:1 for all estimated equations except those including ECC-C and ECC-WS, which used the sample period 1982:1-2000:1.

Table 6
Phillips Curve Estimates from State Data

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \nu_{it+1}$$

	OLS		**IV**	
Phillips Curve Slope (SE)	-0.165 (0.045)	-0.409 (0.070)	-0.208 (.061)	-0.586 (0.113)
Year Effects P-Value	0.00	0.00	0.00	0.00
State Effects P-value	Excluded	0.81	Excluded	0.94
R^2	0.26	0.29	NA	NA

Notes: N=912 (1979-1997). IV estimates use even months of MORG as instrument for odd months.

Table 7
Alternative Phillips Curve Estimates

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} \;=\; \alpha_i + \delta_t + \beta u_{it} + v_{it+1}$$

Deviation of Specification from Benchmark	PC Slope (SE)
(0) None	-0.586 (0.113)
(1) IV Odd month IV for Even Months	-0.447 (0.113)
(2) Weighting by Size of State Workforce	-0.542 (0.089)
(3) Adjusted Wages^2 and Unemployment Rate^1	-0.506 (0.097)
(4) Adjusted Unemployment Rate^1	-0.586 (0.113)
(5) Adjusted Unemployment Rate^2	-0.534 (0.129)
(6) Adjusted Wages^2	-0.552 (0.098)
(7) Wages – Median/All	-0.625 (0.151)
(8) Wages – Mean/Full Time	-0.526 (0.128)
(9) Wages – Mean/Hourly	-0.660 (0.119)
(10) Productivity Growth Omitted	-0.637 (0.092)
(11) Productivity Growth Uses as a Regressor	-0.654 (0.094)
(12) Weighted Industry Productivity Growth	-0.718 (0.095)
(13) Productivity Growth dated "t"	-0.418 (0.114)
(14) Unemployment dated "t+1"	-0.385 (0.112)

Notes: The table shows estimates of the Phillips curve slope and associated standard error for alternative specifications. The first column describes the deviation from the benchmark model (given in the last column of table 6 and labeled (0) in this table). Specification (1) reverses the role of instruments and regressors in the baseline specification. Specification (2) uses weighted IV, where the weights are the size of the state workforce. Specifications (3)-(6) use adjusted values for wages and/or the unemployment rate. Variables with a "1" subscript were adjusted using cross-section regressions each year that controlled for 10 education categories, 3 race categories, a quartic in potential experience, and an interaction between gender and all other regressors. Variables with a "2" subscript used these regressors together with 11 major industry indicator variables. Specifications (7)-(9) use alternative wage measures: Median hourly wage for all workers, mean hourly wage for full-time workers, and mean hourly wage for workers paid on hourly basis. Specification (10) uses the dependent variables ω_{ti+1}-π_{t+1}, (11) adds θ_{it+1} as a regressor (relaxing the unit elasticity constraint), and (12) uses a weighted industry measure of state productivity growth. Specification (13) used the dependent variable $\omega_{it+1} - \theta_{it} - \pi_{t+1}$, and specification (14) uses u_{it+1} as the regressor. (The results are invariant to the timing of π_t because of the include or time effects.) The sample period for Specification (10) was 1979-98 (N=960), and was 1979-97 (N=912) for all other specifications.

Table 8
Alternate Specification of Phillips Curve Dynamics

A. Relaxing the Unit Root Constraint on Real Wages

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \gamma[\ln(W_{it}/P_t) - \ln(Productivity_{it})] + v_{it+1}$$

Variable	OLS			IV		
Unemployment Rate	-0.401 (.065)	-0.375 (.062)	-0.480 (.049)	-0.581 (.113)	-0.548 (.097)	-0.612 (.089)
Real Wage	-0.103 (.021)	-0.090 (.022)	-0.146 (.015)	-.010 (.034)	-0.028 (.030)	-0.057 (.026)
Productivity Adjustment	Yes	Yes	No	Yes	Yes	No
Adjusted Wages[2]	No	Yes	No	No	Yes	No

Notes: Specifications with "No" productivity adjustment omit the terms θ_{it+1} from the dependent variable and $\ln(Productivity_{it})$ from the regressor. See notes to table 7 for the definition of Adjusted Wages[2].

B. Allowing Distributed Lags

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \alpha_\omega(L)[\omega_{it} - \theta_{it} - \pi_t] + \alpha_u(L)\Delta u_t + v_{it+1}$$

Variable	Coefficient (SE)	
u_{it}	-0.486 (.131)	-0.549 (.161)
$\omega_{it}-\theta_{it}-\pi_t$	0.051 (.103)	0.031 (.107)
$\omega_{it-1}-\theta_{it-1}-\pi_{t-1}$		-0.210 (.094)
Δu_t	-0.404 (.345)	-0.141 (.411)
Δu_{t-1}		-0.020 (.520)
P-Value for $\alpha_\omega(L)=0$	.62	.08
P-Value for $\alpha_u(L)=0$	.24	.86

Notes: The sample period is 1981-97 (N=816)

Table 9:
Stability of Phillips Curve through Time and Space

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta_{it} u_{it} + v_{it+1}$$

Variable	Coefficient (SE)		
u_{it}	-0.586 (.113)	-0.623 (.142)	-0.736 (.139)
$u_{it} \times \mathbf{1}(t\ \ 1984)$		0.066 (.143)	
$u_{it} \times \mathbf{1}(t\ \ 1992)$		0.014 (.204)	
$u_{it} \times \mathbf{1}(i \text{ in Northeast})$			0.509 (.198)
$u_{it} \times \mathbf{1}(i \text{ in North Central})$			0.065 (.159)
$u_{it} \times \mathbf{1}(i \text{ in West})$			0.214 (.203)
Temporal Stability p-Value		0.895	
Spatial Stability p-Value			0.065

Notes: The sample period is 1979-1997 (N=912). The temporal stability p-value is associated with the Wald test for the hypothesis that the coefficients on u_{it} interacted with the time indicators are zero. The spatial stability p-value is associated with the Wald test for the hypothesis that the coefficients on u_{it} interacted with the region indicators are zero.

Table 10
Demographic Variables and the Phillips Curve

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \gamma X_{it} + v_{it+1}$$

Variable	Coefficient (SE)					
Unemployment rate	-0.586 (.113)	-0.642 (.147)	-0.550 (.134)	-0.604 (.120)	-0.542 (.159)	-0.526 (.320)
%High School Dropout		-0.099 (.140)				-0.081 (.189)
%College Graduate		0.299 (.345)				0.577 (.918)
%White			0.233 (.543)			0.164 (2.000)
%Female				-0.328 (.621)		0.030 (1.378)
%Age 25-54					-0.113 (.285)	-0.381 (.981)
Education Variables p-Value		0.339				0.704
All Demographics p-Value						0.712

Notes: The sample period is 1979-97 (N=912).

Table 11
Industry Characteristics and the Phillips Curve

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \gamma X_{it} + v_{it+1}$$

Variable	Coefficient (SE)					
Unemployment rate	-0.586 (.113)	-0.823 (.170)	-1.084 (.397)	-0.599 (.115)	-0.575 (.115)	-0.854 (.179)
%Durable Mfg.		0.333 (.227)				0.196 (.283)
%Non-durable Mfg.		-0.166 (.303)				-0.247 (.312)
%Retail Trade		0.275 (.708)				0.161 (.715)
%Services		1.045 (.501)				1.113 (.526)
%Temp Help (CPS)			-19.239 (13.567)			
%Temp Help (CBP)				-0.290 (.324)		-0.159 (.383)
%Self-Employed					-0.196 (.272)	-0.437 (.487)
Major Industry p-Value		0.153				0.164
All Industry Variables p-Value						0.312

Notes: The sample period is 1979-97 (N=912).

Table 12
Government Policy Variables and the Phillips Curve

$$\omega_{it+1} - \theta_{it+1} - \pi_{t+1} = \alpha_i + \delta_t + \beta u_{it} + \gamma X_{it} + v_{it+1}$$

Variable	Coefficient (SE)				
Unemployment rate	-0.586 (.113)	-0.576 (.120)	-0.603 (.114)	-0.591 (.114)	-0.600 (.122)
%Of 25-64 on DI		0.360 (.606)			0.376 (.611)
%Of 25-64 on SSI		0.046 (.577)			0.025 (.578)
Minimum Wage (99$)			-0.414 (.864)		-0.354 (.879)
%Growth in Min. Wage			-0.085 (.049)		-0.084 (.049)
UI Replacement Rate				0.015 (.043)	0.017 (.043)
DI/SSI Variables p-Value		0.746			0.749
Min. Wage Variables p-Value			0.207		0.210
All Policy Variables p-Value					0.566

Notes: The sample period is 1979-97 (N=912).

Figure 1a
Price Inflation and Unemployment

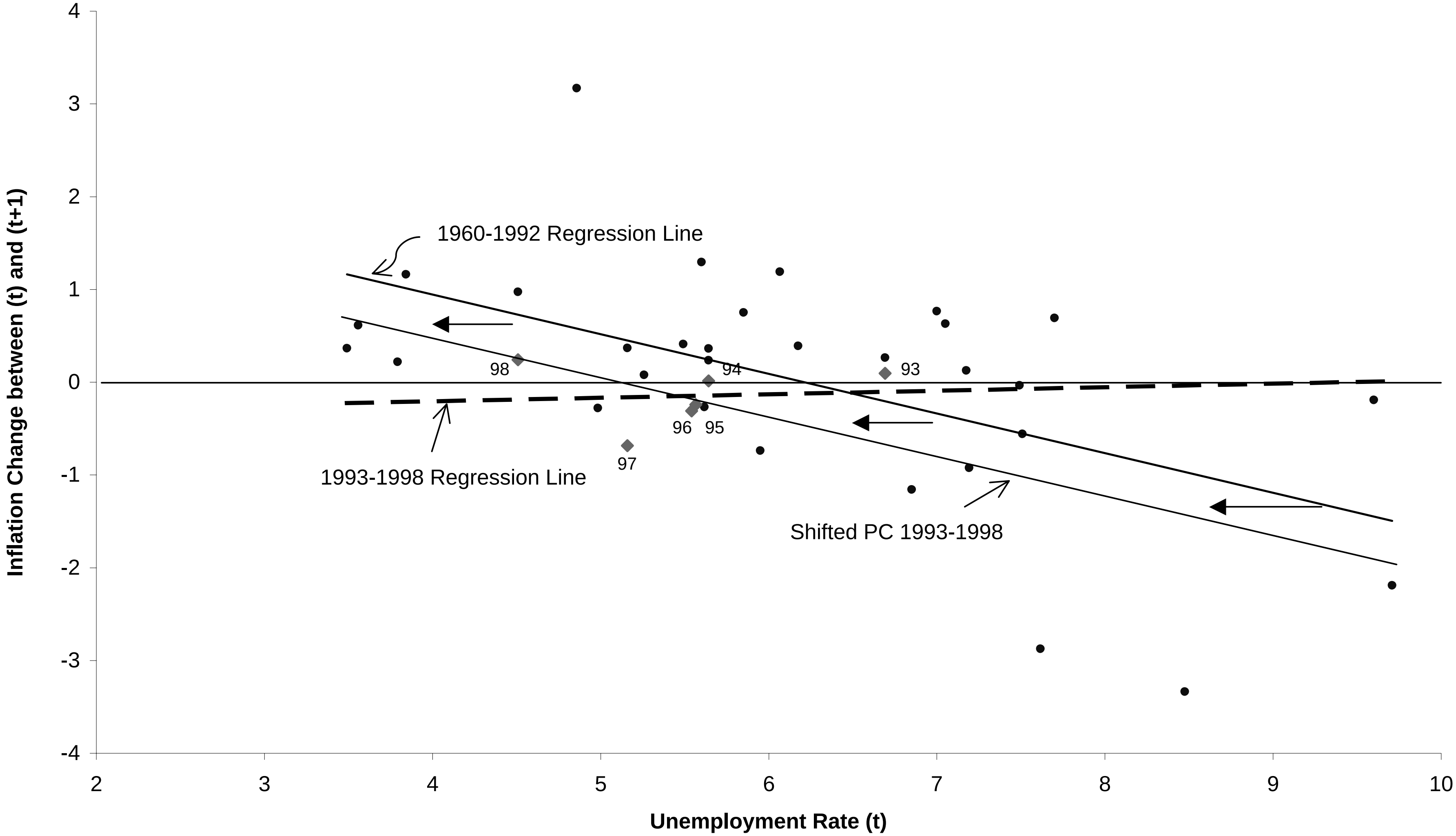

Figure 1b
Real Wage Inflation and Unemployment

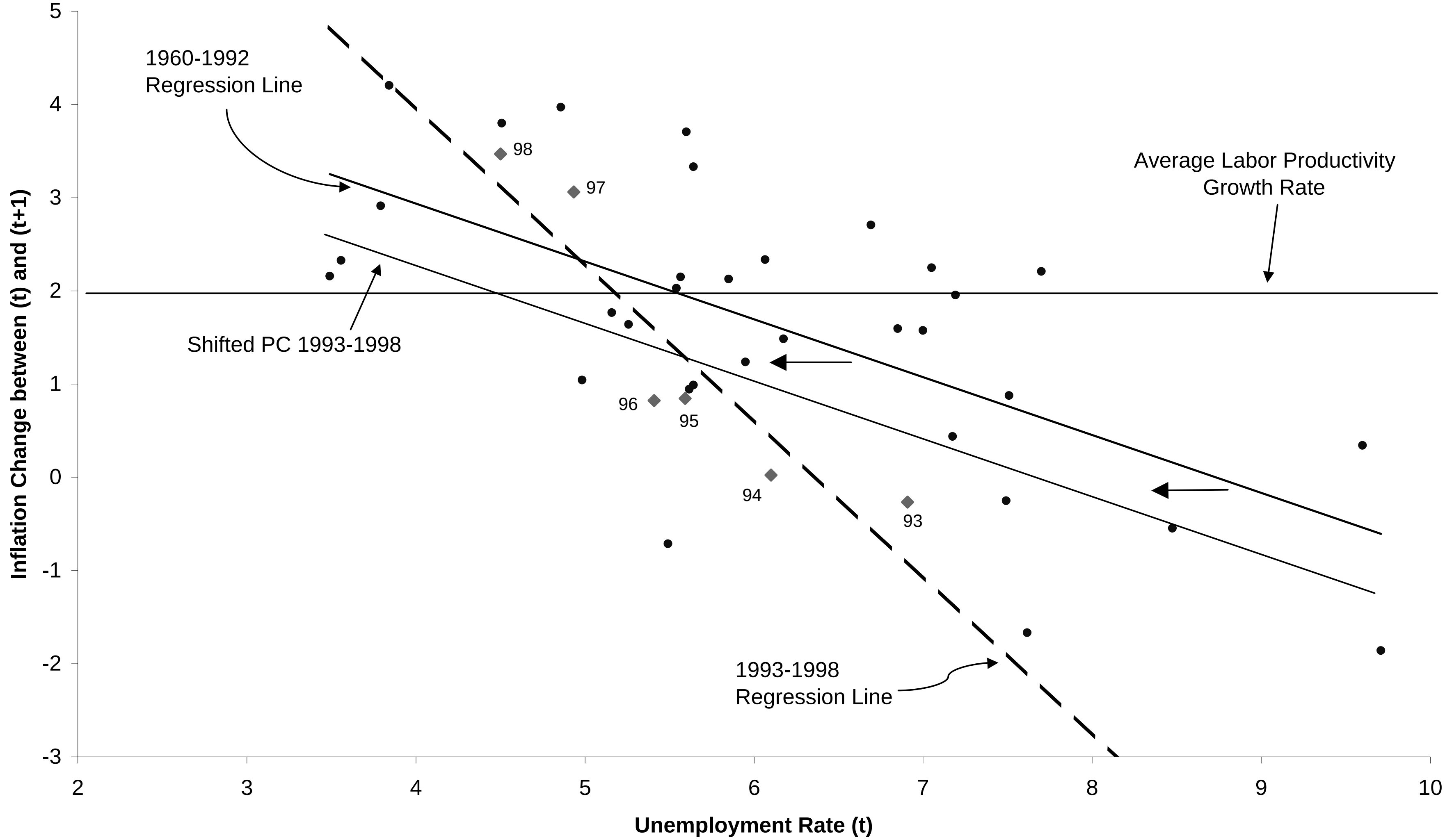

Figure 2. Macro Series and their Trend Values

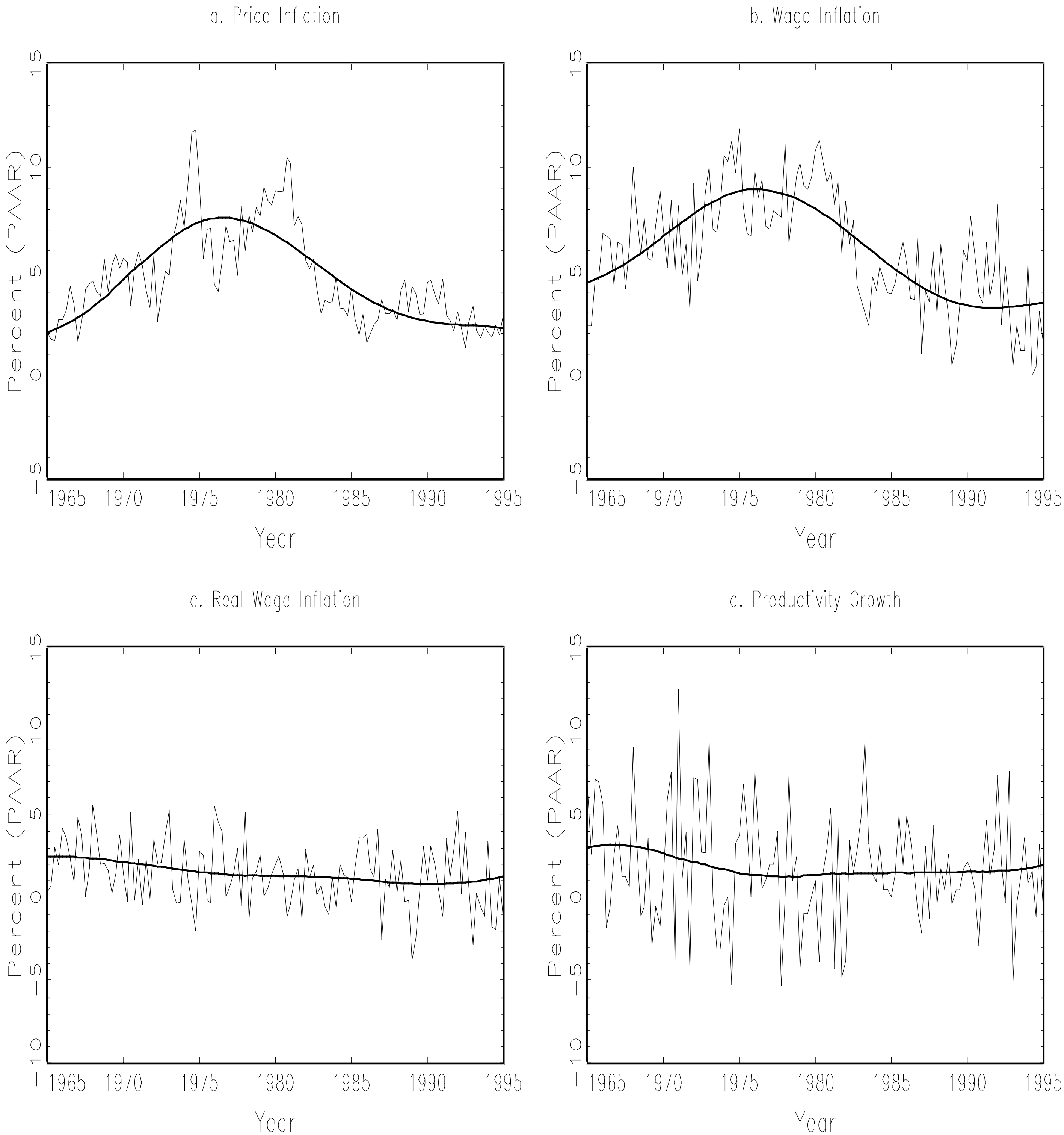

Figure 2. (Continued)

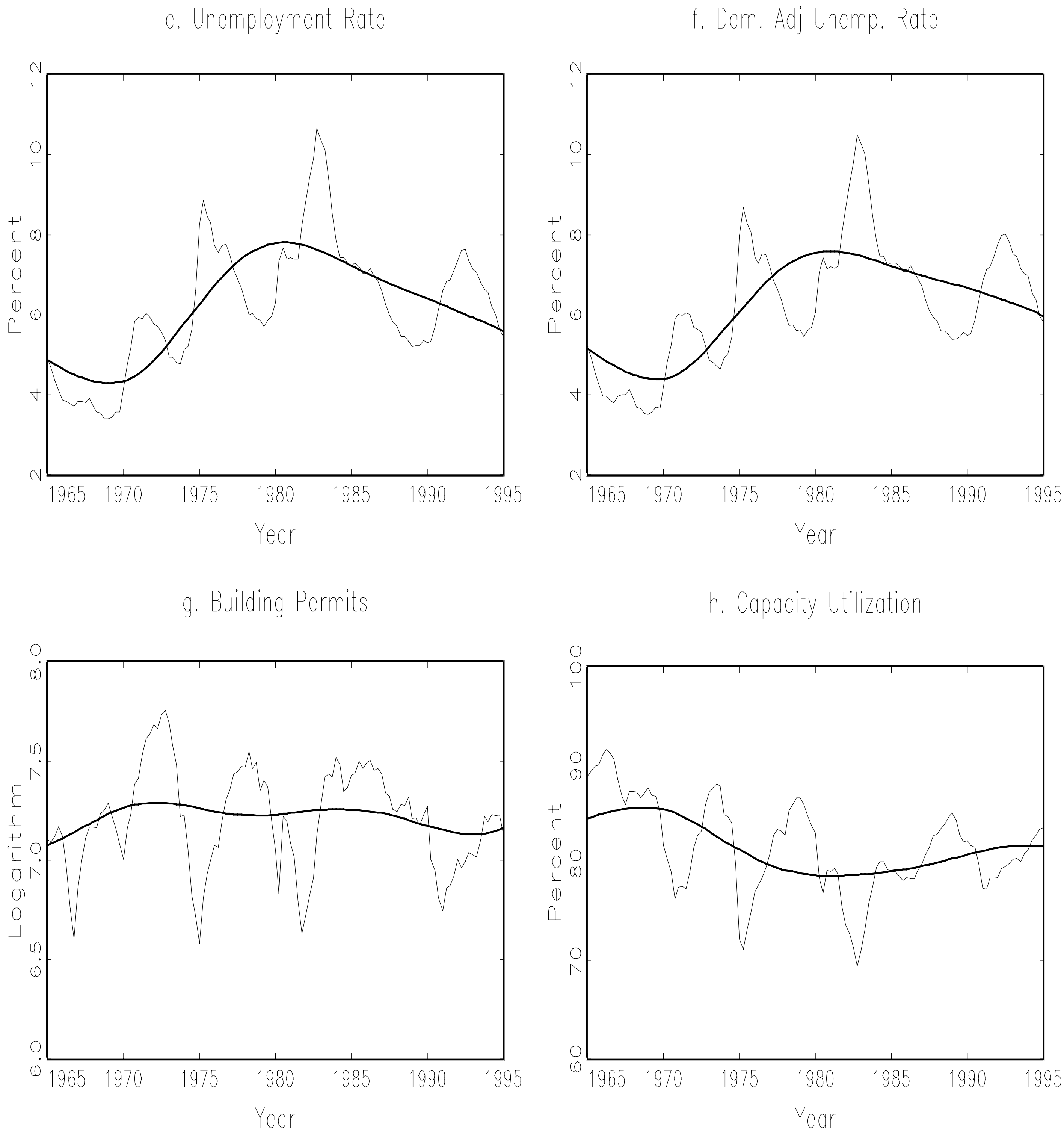

Figure 3
NAIRU From Price Phillips Curve

Figure 4
Slope from Baseline Price Phillips Curve

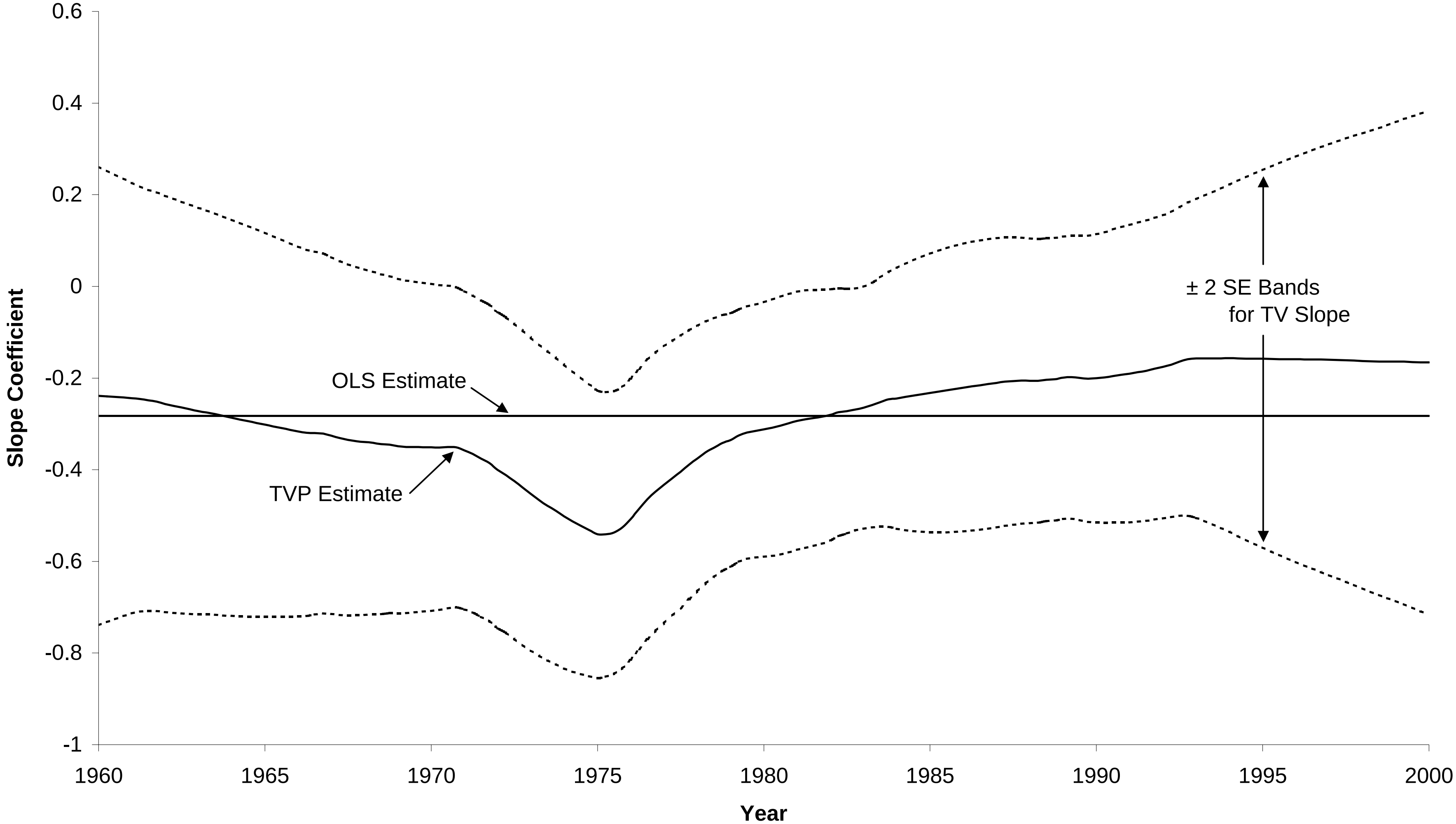

Figure 5
NAIRU From Wage Phillips Curve

Figure 6
Slope from Baseline Wage Phillips Curve

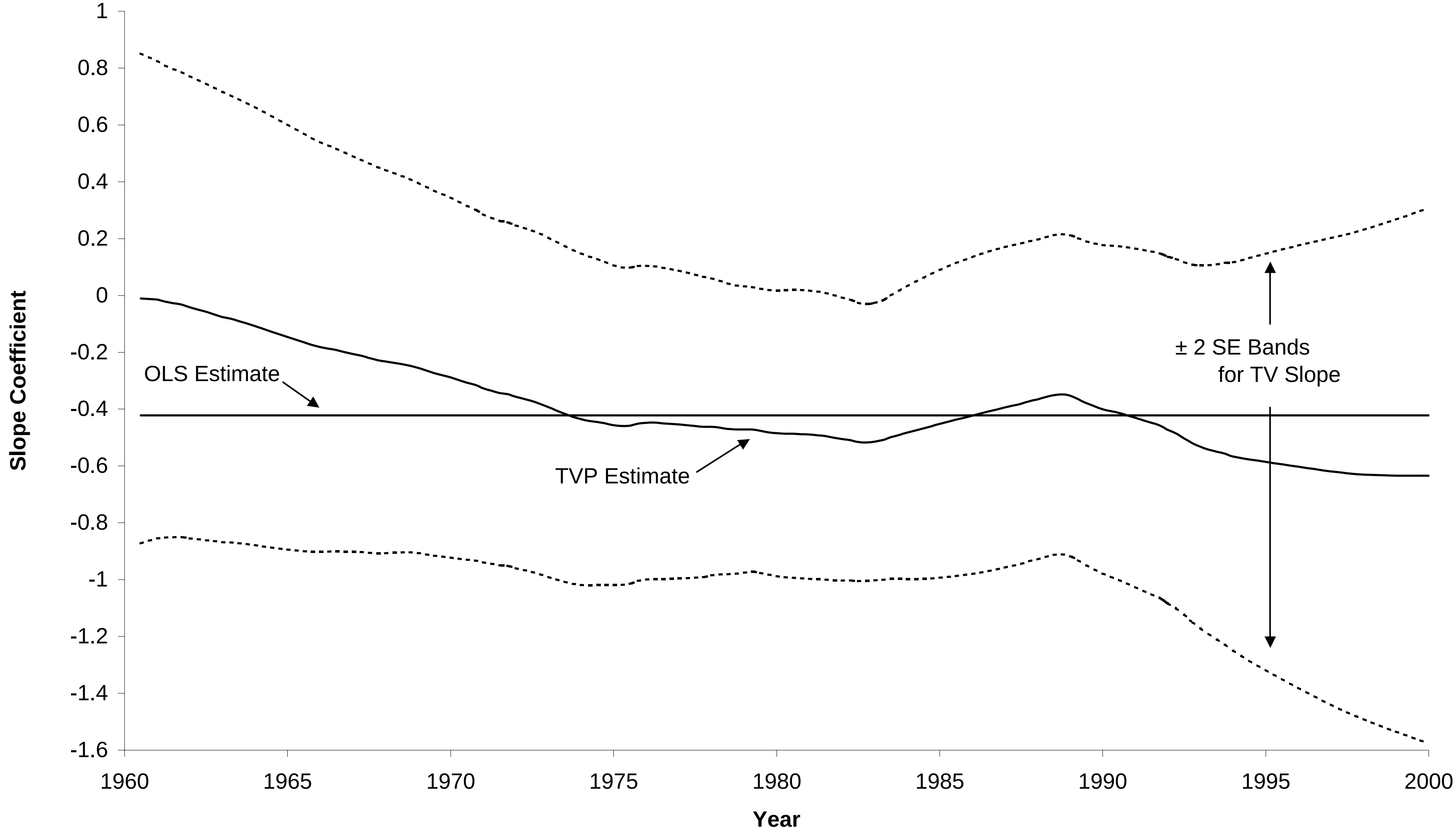

Figure 7
State Estimates of TV NAIRU

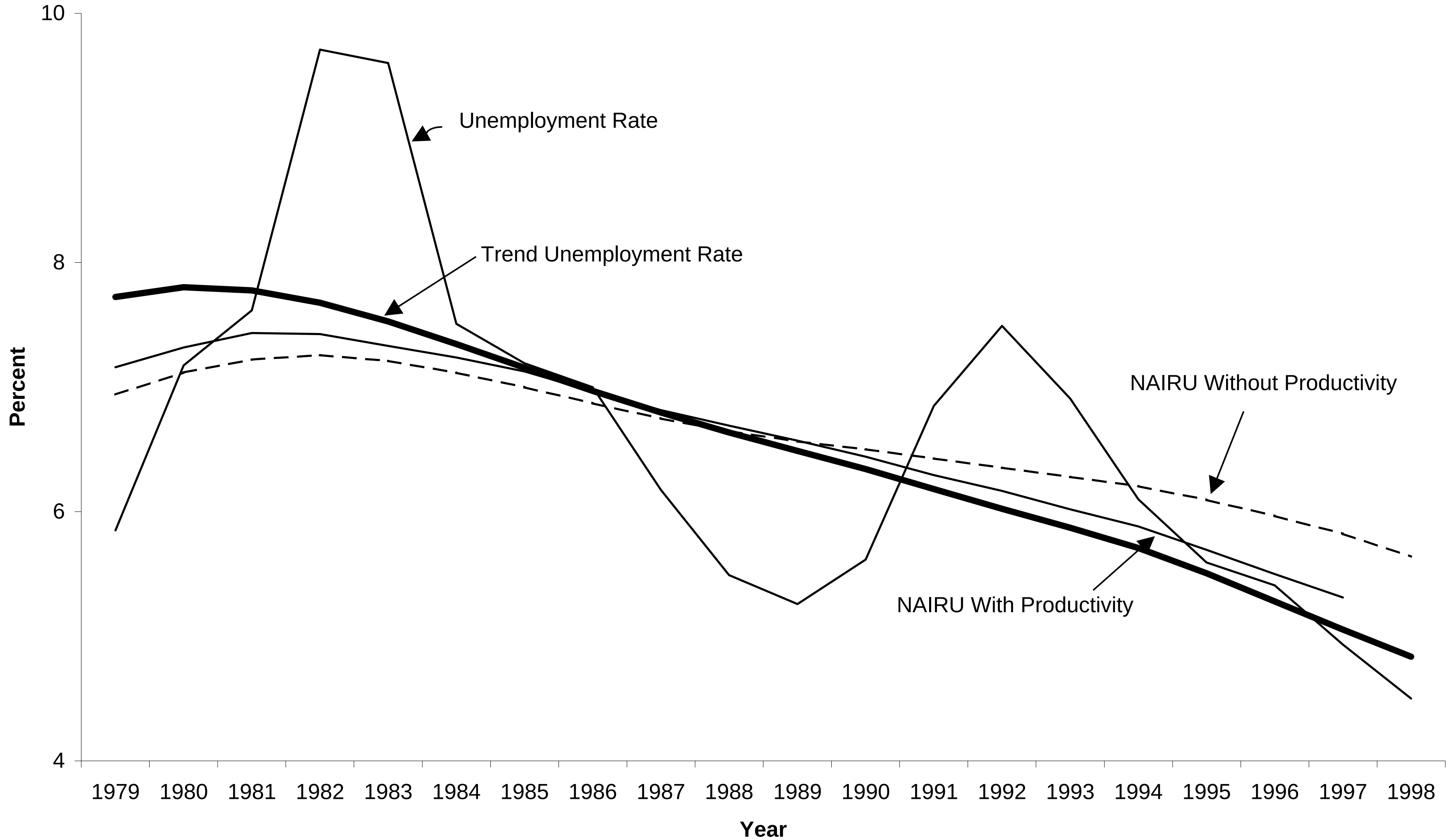

Figure 8a
Trend Unemployment and Productivity Growth

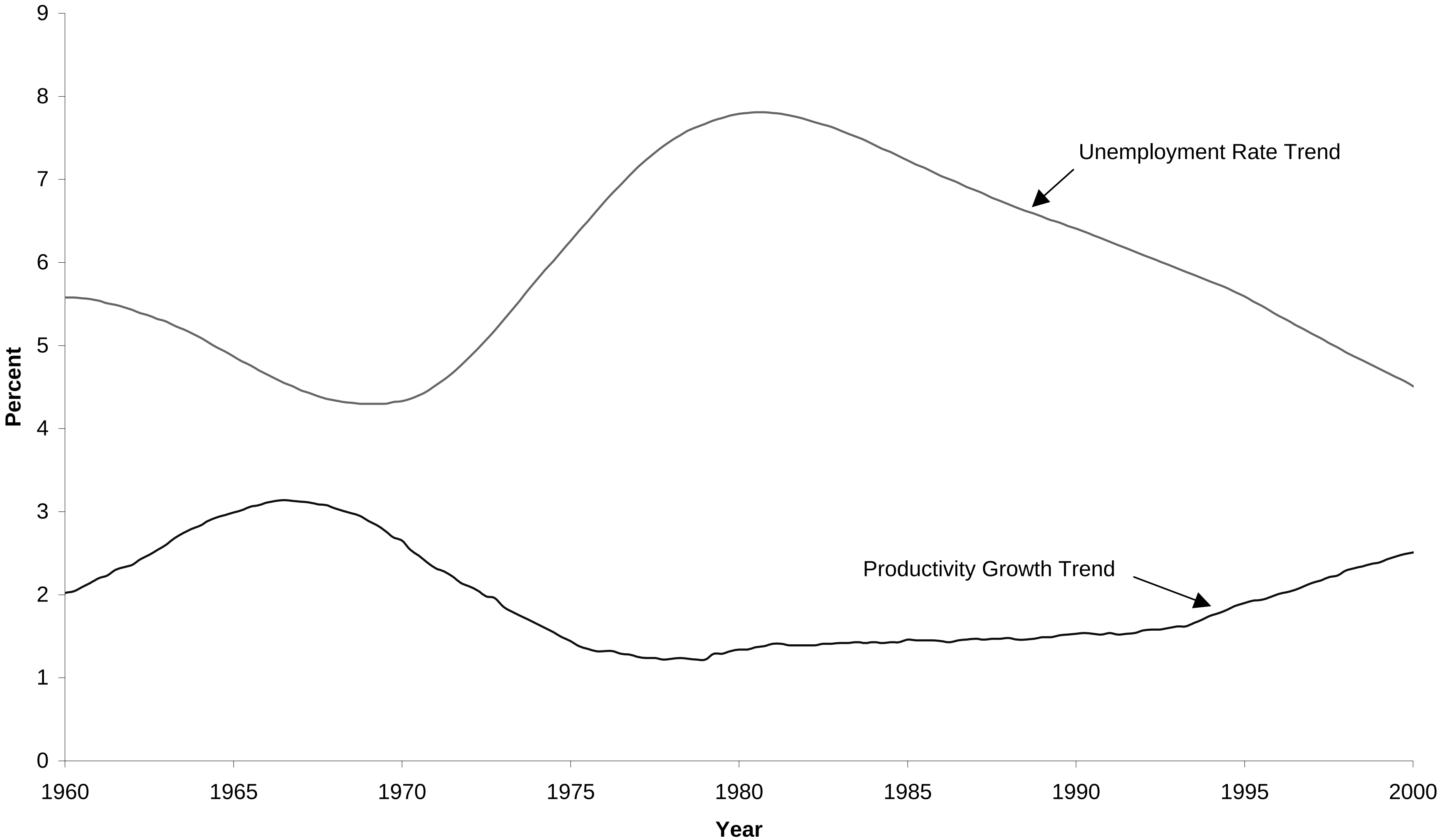

Figure 8b
Unemployment Rate and Productivity Growth Trends