PRODUCTIVITY GROWTH AND THE PHILLIPS CURVE

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I. INTRODUCTION

The "New Economy" in the U.S. since the mid-1990s has featured surprisingly benign behavior of inflation and unemployment. Before this experience, most estimates of the NAIRU -- the non-accelerating inflation rate of unemployment -- were in the neighborhood of six percent. Yet unemployment has fallen far below this level, reaching 4.2% in 1999, and inflation has failed to rise substantially. This paper presents an explanation for the apparent improvement in the unemployment-inflation tradeoff. We argue that it is caused by another feature of the new economy: the rise in the growth rate of labor productivity.

Our argument builds on an old idea: workers' wage aspirations adjust slowly to shifts in productivity growth. As a result, such shifts produce periods when aspirations and productivity are out of line, causing the Phillips curve to shift. Authors such as Grubb et al. (1982) use this idea to argue that the productivity slowdown of the 1970s caused an unfavorable Phillips-curve shift. Authors such as Blinder (2000) and Council of Economic Advisors (2000) suggest that this process worked in reverse in the late 1990s, with a productivity speedup causing a favorable Phillips-curve shift.
This paper presents new evidence that changes in productivity growth do indeed affect the Phillips curve. In addition to documenting this idea in general, we show that it explains most of the Phillips curve puzzle since 1995.

Our argument proceeds in several steps. In Section II, we discuss the ideas about wage determination that underlie our story. We draw on previous research showing that concepts of fairness have important impacts on wage setting, and that perceptions of fair wage increases are tied to past wage increases.

Section III embeds these ideas in an otherwise standard model of the Phillips curve. In the model, an increase in productivity growth feeds one-for-one into lower price inflation for given wage inflation. It has little effect on wage inflation, which is determined largely by past wage increases. Wage inflation also depends negatively on unemployment. Combining the wage and price equations yields a Phillips curve in which the change in inflation depends on unemployment and the difference between current productivity growth and past real-wage growth. Shifts in productivity growth cause shifts in the unemployment-inflation relation for a period while wage aspirations are adjusting.

Section IV discusses the measurement of key variables in
our model, and Section V presents our central empirical results. We estimate alternative Phillips curves using annual U.S. data from 1962-1995, and then use these equations to forecast inflation over 1996-1999. We first confirm previous findings that a conventional Phillips curve overpredicts inflation over the last half of the 90s. We then estimate the Phillips curve from our model and find that our new variable -- the gap between productivity growth and past real wage growth -- has the effect on inflation predicted by our theory. When this variable is included, the overprediction of inflation since 1995 disappears. Section VI discusses extensions of our analysis, such as the addition of traditional "supply shock" variables to the Phillips curve.

Section VII briefly leaves our analysis of U.S. data to look for other evidence for our theory. We stress one case study: the Chilean miracle of the 1990s. Chile stands out from the cross-country data in having an unusually large productivity acceleration over 1990-1997. During the same period, Chile also had a favorable shift in its Phillips curve: it disinflated without the usual costs in output and employment. We suggest that the productivity acceleration and Phillips-curve shift are linked in Chile as in the United States.
Section VIII discusses some preliminary work with micro data, and Section IX concludes the paper.

II. WAGE ASPIRATIONS

It is clear that real wages are closely tied to labor productivity in the long run. Consequently, our model will have the feature that productivity, real wages, and real-wage aspirations all grow at the same rate in a steady state. We consider the possibility, however, that a shift in productivity growth is not matched immediately by a shift in wage aspirations, because these are tied partly to past wage increases. Ideas along these lines have been suggested by many authors; recent examples include Blanchard and Katz (1997), Stiglitz (1997), Blinder (2000), and DeLong (2000). However, these authors seldom justify their ideas about wage aspirations in much detail. We will not attempt a full-fledged analysis of aspirations, but we will briefly review some relevant literature.

By "wage aspirations" we mean the real wages that workers consider fair. Our model rests on two key assumptions about aspirations: that they affect the actual wages that workers receive, and that they are tied to past wage increases. We
discuss these points in turn.

The assumption that wages depend on what workers consider fair is a departure from neoclassical microeconomics, but one with strong empirical support. Akerlof and Yellen (1990) discuss a likely channel: workers reduce their effort if they perceive their wages as unfair, making it in firms' interests to pay fair wages. Akerlof and Yellen cite experimental evidence from psychology and sociology showing that the quality of workers' performance falls when they believe wages are unfair. Akerlof and Yellen also cite personnel management textbooks showing that employers take this effect into account in setting wages. Bewley's (2000) recent field research suggests the similar idea that firms pay fair wages to maintain worker morale. The older labor-economics literature also contains evidence along these lines.

Our theory assumes that workers' aspirations -- their perceptions of fair real-wage increases -- depend on past real-wage increases. Oswald (1986) cites studies by psychologists [to be reviewed in future drafts] suggesting that workers' concepts of fair wages are tied to their past wages. The studies cited by Akerlof and Yellen suggest a somewhat different idea: fair wages are determined by the wages of other workers. This idea is reminiscent of the old
labor-economics idea of pattern bargaining: one union's demands for wage increases depend on the increases received by other unions. Thus, in discussing fair wages, Oswald stresses one's own past wage while Akerlof and Yellen stress comparison to others. These are different ideas at the micro level, but they appear to have similar aggregate implications. If wage setters look to past wage increases to determine their current behavior, aggregating across the economy yields a relationship between wage increases and lagged wage increases, regardless of whose past increases are relevant to individuals. This research will look for an aggregate relationship; future work with micro data can examine the issue of whose wage matters.1

III. THE PHILLIPS CURVE AND THE NAIRU

This section embeds our ideas about wage aspirations in a canonical model of wage- and price-setting and derives a Phillips curve. Specifically, the model follows Blanchard and Katz (1997) and Katz and Krueger (1999) except for our treatment of productivity and aspirations.

A. Deriving the Phillips Curve

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1 One subtlety is why ideas about fairness concern wage increases rather than wage levels. The likely reason is that productivity growth and life-cycle effects cause workers to become accustomed to fairly steady increases rather than fairly steady levels. (Similarly, individuals have backward-looking expectations about inflation rather than price levels because they have
We denote inflation by \( \pi \) and wage inflation by \( \pi^w \), so real wage growth is \( \pi^w - \pi \). We assume that wage setters have a target for real-wage growth given by

\[
\text{(1)} \quad (\pi^w - \pi)^* = \alpha - \gamma U + \delta g + (1-\delta)A + \eta, \quad \alpha, \gamma > 0, \ 0 \leq \delta \leq 1,
\]

where \( U \) is unemployment, \( g \) is labor-productivity growth, \( A \) is an aspiration wage increase, and \( \eta \) is an error term. This equation makes the conventional assumption that higher unemployment reduces target real-wage growth. The target also depends on an average of productivity growth and the aspiration wage increase, which is given by

\[
\text{(2)} \quad A = \frac{1 - \beta}{\beta} \sum_{i=1}^{\infty} \beta^i (\pi^w \pi)_{-i},
\]

To interpret equations (1)-(2), consider first the special case of \( \delta = 1 \). This is a neoclassical benchmark in which productivity growth feeds one-for-one into wages, and aspirations are irrelevant. At the other extreme of \( \delta = 0 \), productivity is irrelevant and wage increases are based on aspirations. This period's aspiration for a real-wage increase is a weighted average of past increases, with exponentially declining weights. The aspiration real-wage increase can also be written recursively as

\[
A = \beta A_{-1} + (1-\beta)(\pi^w - \pi)_{-1}.
\]

As this shows, aspirations adjust over time in experienced fairly steady inflation rates.)
response to the most recent wage increase. The adjustment is fast if $\beta$ is small and slow if $\beta$ is close to one.

Our model nests the two special cases, allowing both productivity growth and past real-wage growth to influence wage setting. Note we assume that these two variables have coefficients that sum to one. This implies that the target depends one-for-one on productivity growth in a steady state with real-wage growth constant and equal to productivity growth.

Wage setters must choose nominal wages one period in advance. They choose a nominal wage increase $\pi^w$ equal to their target real wage increase, $(\pi^w-\pi)^*$, plus expected inflation. Expected inflation equals last period's inflation, $\pi_{-1}$. Combining these assumptions with equation (1) yields a "wage Phillips curve":

\[ (3) \quad \pi^w = \alpha + \pi_{-1} - \gamma U + \delta g + (1-\delta)A + \eta. \]

Wage inflation depends on past price inflation, unemployment, and an average of $g$ and $A$.

We complete the model with a standard equation for price inflation:

\[ (4) \quad \pi = \pi^w - g + \nu, \]

where $\nu$ is another error. Price increases depend one-for-one
on the increase in unit labor costs, which is wage inflation minus productivity growth. Substituting the wage Phillips curve into (4) yields a "price Phillips curve":

\[ \pi = \alpha + \pi_{-1} - \gamma U - (1-\delta) (g-A) + \epsilon , \]

where \( \epsilon = \eta + \nu \). This Phillips curve will be the centerpiece of our empirical analysis.

B. Discussion

To interpret our Phillips curve, we again start with the case of \( \delta = 1 \): target real-wage increases depend on productivity growth but not on aspirations. In this case, the \( g-A \) term drops out of (5), and the equation reduces to a conventional accelerationist Phillips curve. For \( \delta = 1 \), productivity growth has a negative effect on price inflation given wage inflation, but it has a fully-offsetting positive effect on wage inflation. Thus productivity growth has no role in the Phillips curve. Since \( \delta = 1 \) is a natural neoclassical baseline, this result explains why research on the Phillips curve does not usually emphasize productivity growth.

Productivity growth does matter if wage growth is partly tied to past wage growth, i.e. \( \delta < 1 \). Productivity growth is still irrelevant in a steady state with \( g = A \). But if productivity growth accelerates or decelerates, \( A \) does not
adjust immediately, and g-A moves in the direction of g. A productivity acceleration causes a favorable shift in the unemployment-inflation relation and a slowdown causes an unfavorable shift. The shift can last a long time if the parameter $\beta$ is close to one -- if wage aspirations adjust slowly.

While the aspiration variable $A$ can be out of line with productivity growth, the **actual** growth of real wages cannot be. Inverting the price equation (4) gives a formula for actual real-wage growth: it equals $g + \nu$. In equilibrium, this fact is reconciled with the behavior of wage setters by movements in unemployment or inflation. During a productivity slowdown, target wage growth rises relative to productivity growth **for given unemployment**, but higher unemployment offsets this effect or accelerating inflation reduces actual real-wage growth below the target. Thus the model is consistent with the stylized fact that U.S. wages are closely tied to labor productivity, as shown by the near-constancy of labor's share of income.

We define the NAIRU in our model as the level of unemployment consistent with stable inflation and $g-A=0$, which must hold in steady state. The NAIRU can be computed as $-\alpha/\gamma$, the ratio of the constant in the Phillips curve to minus the
unemployment coefficient. If a productivity acceleration raises g-A above zero, we will say that unemployment can fall below the NAIRU temporarily without accelerating inflation, not that the NAIRU itself has fallen. In other words, we treat movements in g-A as "supply shocks" that shift the unemployment-inflation tradeoff for a given NAIRU.

IV. DATA AND MEASUREMENT

Our measurement of inflation and unemployment follows the previous literature, especially Blanchard-Katz (1997) and Katz- Krueger (1999). The data are annual. The inflation rate \( \pi \) is the change in the log of the consumer price index, and the wage-inflation rate \( \pi^w \) is the change in the log of compensation per hour in the business sector. Unemployment is the civilian unemployment rate. All of these series are produced by the Bureau of Labor Statistics.

The rest of this section discusses construction of the two key variables in our theory: the growth rate of labor productivity, \( g \), and aspirations for real-wage growth, \( A \).

A. Measuring Productivity Growth

Our starting point for measuring productivity growth is the change in the log of output per hour in the business sector, from the BLS. As shown below, this series captures
both the productivity slowdown of the 1970s and the speedup since 1995. For our present purposes, the reasons for these productivity shifts are not important. For example, we need not take a stand on whether the recent acceleration in productivity reflects rapid TFP growth or capital deepening.2

A key practical issue in measuring productivity is cyclical adjustment. There is widespread agreement that output per hour is an imperfect measure of labor productivity because labor input varies through shifts in worker effort as well as measured hours. In particular, productivity growth is overstated in expansions because effort rises. In our underlying theory, price- and wage-setting depends on true rather than measured productivity, so we need to adjust our productivity variable to eliminate the effects of cyclical movements in effort.

Our approach to measuring true productivity follows Basu and Kimball (1996), who build on Bils and Cho (1994). Basu and Kimball's key assumption is that, over the business cycle, effort moves proportionately with average weekly hours of employed workers. This relationship follows from a model in which firms can costlessly adjust both effort and weekly hours

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2 We splice the BLS’s published series for output per hour, which begins in 1959, to an unpublished series for 1947-1958.
when they need more labor input (but adjusting employment may be costly). Empirically, a close link between effort and weekly hours is supported by time-motion studies that directly measure effort (Schor, 1987). Given this link, we can use variation in weekly hours as a proxy for variation in effort.

We purge measured fluctuations in productivity growth of the part caused by changes in effort by regressing productivity growth on the change in the log of weekly hours, $\Delta h$. The residuals from this regression capture true fluctuations in productivity growth.

For 1962-1999, regressing measured productivity growth on $\Delta h$ yields a coefficient of 0.70. To construct true productivity growth, $g$, we subtract $(0.70)\Delta h$ from measured productivity growth. We add a constant to make the mean of $g$ equal to the mean of measured productivity growth.

Figure 1 graphs our series for $g$ from 1962 through 1999. The data capture the broad phenomena of the productivity slowdown and the recent acceleration: $g$ averages 3.3% over 1962-1973, 1.5% over 1974-1995, and 2.6% over 1996-1999. However, these broad trends do not fully explain the data. There is considerable year-to-year variation in productivity growth, even after our cyclical adjustment.

B. Wage Aspirations
The most novel variable in our analysis is $A$, which determines workers' aspirations for real-wage increases. In each period, $A$ is an exponentially-weighted average of past real-wage increases (equation (2)). Two issues arise in constructing $A$: the choice of the weighting parameter $\beta$, and the need to approximate the infinite sum in the definition of $A$. We begin with the second issue.

In principle, $A$ depends on real-wage increases back to the infinite past. In practice, our data on real-wage growth start in 1948. To address this problem, we make a reasonable guess of the value of $A$ in 1948. Given this value, we can derive $A$ for 1949, 1950, ... using the recursive definition of $A$, $A=\beta A_{-1}+(1-\beta)(\pi^w-\pi)_{-1}$. That is, we assume an $A$ in 1948 and update $A$ in each year based on the evolution of real wages.

Specifically, we set $A$ for 1948 equal to trend real-wage growth in that year, as measured by the Hodrick-Prescott filter over 1948-1999 with smoothing parameter 1000. This yields $A=3.2\%$. The implicit assumption is that wage aspirations in 1948 were in line with the actual trend in real wages: 1948 was not a time like the 1970s or late 90s when aspirations and actual wage-growth diverged. Fortunately, our results are not very sensitive to our choice of $A$ for 1948, because our regressions use data starting in 1962. The 1948
value of $A$ has a weight of only $\beta^{14}$ in the formula for $A$ in 1962, and smaller weights in later $A$'s.3

The exponential parameter $\beta$ can in principle be estimated from the data. Our estimates are imprecise, however, and so we end up imposing values that are plausible a priori and not rejected by the data. Figure 2 shows the time series for actual real-wage growth from 1948 through 1999 and for $A$ with various values of $\beta$. Real-wage growth fluctuates around a trend that is fairly stable from 1948 through the late 1960s and then declines as a result of the productivity slowdown. For most values of $\beta$, $A$ follows the downward trend in real-wage growth with a lag, as aspirations adjust slowly. Real-wage growth rises sharply and aspirations modestly at the end of the sample.

In much of our analysis, we will focus on the case of $\beta=0.95$. This value is high enough to capture Stiglitz's

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3 We add a constant to the series on real-wage growth to make its mean equal the mean of productivity growth, $g$. That is, we impose the restriction that there is no trend in labor’s share of income. The means of real-wage growth and productivity growth differ in the raw data, mainly because the average growth of the price index used to construct real output per worker is lower than the average growth of the consumer price index used to construct real wages.
(1997) suggestion that the adjustment of aspirations to the 1970's productivity slowdown continued into the 1990s. Moreover, values that are much smaller than 0.95 or very close to one seem less appealing. As illustrated in Figure 2, values of 0.8 or below imply that aspirations fluctuate substantially in response to year-to-year fluctuations in actual real-wage growth. It seems unlikely that concepts of fair wages fluctuate so much. At the other extreme, a $\beta$ of 1.0 implies that workers still want the wage increases they received in the 1950s. In this case, the real-wage growth of the last four years falls short of aspirations; the fact that it is high compared to the previous 25 years is irrelevant.

For $\beta=0.95$, Figure 3 shows the difference $g-A$, the new term that appears in our Phillips curve, for 1962-1999. To isolate long-run trends, the Figure also presents a smoothed version of the series based on the Hodrick-Prescott filter with a parameter of 100. The recent "New Economy" can be seen in the high values of $g-A$ for 1996-1999. High values occurred in some previous years, such as 1992 and 1986, but the run of high values starting in 1996 is unusual. The average value of $g-A$ over 1996-1999 is the highest for any four-year period since 1948. $g-A$ was high in the late 90s because $g$ rose sharply and $A$ reached low levels after finally adjusting to
the productivity slowdown. Productivity growth was higher in
the 50s and 60s, but then it was balanced by high wage
aspirations.

V. ESTIMATES OF THE PHILLIPS CURVE

This section estimates the Phillips curve from our model, equation (5), with annual U.S. data. We examine the general performance of the equation by estimating it with data from 1962 through 1995. We then perform out-of-sample forecasts to see whether the equation explains inflation in the post-1995 New Economy.

A. A Conventional Phillips Curve

As a benchmark, we first examine a Phillips curve that lacks our new variable \( g-A \). This is a simple textbook equation: the change in inflation depends on a constant and unemployment.

As discussed above, this equation follows from our model if wage growth depends one-for-one on productivity growth and aspirations have no effect.

For 1962-1995 -- the Old-Economy period -- ordinary-least-squares estimation of the Phillips curve yields

\[
\Delta \pi = 4.40 - 0.707U, \quad R^2=0.34, \\
(1.15) (0.161)
\]
where standard errors are in parentheses. These results look reasonable. One point-year of unemployment reduces inflation by seven tenths of a percent. The implied NAIRU -- the ratio of the constant to minus the unemployment coefficient -- is 6.2%.

Using these estimates, we next compute forecasts of inflation over 1996-1999, given the actual evolution of unemployment. Figure 4 plots the forecasts along with two-standard-error bands, and compares them to actual inflation. This Figure shows why many authors have suggested that a New Economy has arrived. Since unemployment falls far below the NAIRU estimate of 6.2%, predicted inflation rises rapidly and reaches 6.9% in 1999. In contrast, actual inflation changes little over 1995-1999 and ends at 2.2%. The overprediction of inflation implied by a 6.2% NAIRU suggests that the NAIRU has fallen for some reason.

**B. The Phillips Curve with g-A**

We now estimate the Phillips curve from our model, equation (5). This is the conventional Phillips curve estimated above with the addition of the term g-A.

Our modification of the Phillips curve introduces the parameter $\beta$, the weighting factor in the formula for A. Table 1 presents Phillips-curve estimates for 1962-1995 with
different values of $\beta$ imposed. The Table also reports joint estimates of $\beta$ and the Phillips-curve coefficients obtained by non-linear least squares. The NLLS estimate of $\beta$ is imprecise: a two-standard-error confidence interval runs from -0.02 to 1.10. This reflects the fact that a wide range of $\beta$'s fit the data equally well: the $R^2$'s are very close when different values of $\beta$ are imposed. The point estimate of $\beta$ is 0.54, which is far from the value of 0.95 that we suggested on a priori grounds. However, there is no evidence against $\beta=0.95$: an F-test of this hypothesis yields $F=0.76$ ($p>0.25$). 

Fortunately, we can draw conclusions from the data without knowing the value of $\beta$. As illustrated in Table 1, the coefficient on $g-A$ is significantly negative for all $\beta$'s from zero to one. Thus, as implied by our model, a rise in productivity growth relative to wage aspirations has a negative effect on inflation. The coefficient on $g-A$ is usually near -0.6. In terms of underlying parameters, this means that the aspiration term $A$ has a weight of 0.6 in the expression for target wage-growth and productivity growth has

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4 This p-value is based on an F-test that compares the sum of squared residuals with and without the restriction that $\beta=0.95$. Following Staiger et al. (1998), we use this test because it appears more accurate than a test based on the asymptotic standard error. The standard error does not capture the fact that the model's goodness of fit is roughly constant for $\beta$'s between
a weight of 0.4 (equation (1)). The $R^2$'s for the various $\beta$'s usually exceed 0.5, compared to 0.34 for the equation without g-A. Thus our new variable explains a significant part of inflation variation over 1962-1995.

Figure 5 shows forecasts for inflation over 1996-1999 for various values of $\beta$. In most cases, adding g-A to the Phillips curve dramatically improves the accuracy of the forecasts. For $\beta$'s ranging from 0.5 to 0.95, predicted inflation in 1999 ranges from 1.8% to 2.7%, compared to actual inflation of 2.2%. Thus our model essentially eliminates the overprediction of inflation since 1995. Our equation predicts that inflation stays low despite low unemployment because the productivity acceleration produces high values of g-A.

The only qualification is that our equation overpredicts inflation if $\beta$ is very close to one. As discussed above, $\beta=1$ implies that wage aspirations over 1996-1999 are still tied to the rapid wage growth of the 1950s. In this case, g-A is negative for most of 1996-1999, so including it in the model does not reduce inflation forecasts. Our story about the New Economy depends on the assumption that $\beta<1$; there must be some adjustment of aspirations over time.

0.5 and 1.0 but drops off sharply for $\beta>1.0$. 

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C. Short-Run and Long-Run Variation in g-A

Our results partly reflect broad trends in the data. In the early 1970s, the productivity slowdown reduced g-A, and the unemployment-inflation tradeoff worsened; these facts help produce the negative coefficient on g-A in the pre-1996 Phillips curve. Similarly, the success of our model over 1996-1999 reflects the fact that g-A rose while the output-inflation tradeoff improved. However, these broad trends are not the only reason for our model's success. As shown in Figure 3, there is considerable year-to-year variation in g-A because of fluctuations in g. These movements also help explain shifts in the U/π relation.

To make this point, we decompose the variable g-A (for β=0.95) into two components: a trend, given by the HP-filter in Figure 3, and deviations from the trend. For 1962-1995, entering these components separately in the Phillips curve yields the regression

$$\Delta \pi = 3.33 - 0.756U - 1.223(g-A)^T - 0.526(g-A)^D,$$

(1.09) (0.209) (0.513) (0.202)

where (g-A)^T is the trend component of g-A and (g-A)^D is the deviation from trend. Both components have statistically significant effects. The point estimate is higher for the trend component, but one cannot reject the hypothesis that the
two coefficients are equal (p=0.14). Thus both long-term and short-term movements in g-A have the effects predicted by our theory.

Researchers often give different interpretations of long-term and year-to-year shifts in the U/π relation. The former are interpreted as shifts in the NAIRU, and the latter as "supply" or "inflation" shocks. This is the case, for example, in the Kalman-filter approach to estimating time-varying NAIRUs. In contrast, our results suggest that parts of the short-term and long-term shifts in the U/π relation have a common explanation.

D. Is Low Unemployment Sustainable?

This paper is written for a conference on the "sustainability" of today's low unemployment. At first glance, our analysis appears to have pessimistic implications about sustainability. The Phillips curve has shifted favorably because a productivity acceleration has produced positive values of g-A. But when productivity growth stabilizes, aspirations for real-wage growth will eventually adjust to the new trend. In the long run we must see values of g-A that average to zero, implying a worse U/π tradeoff than in the recent period of positive g-A's.

On the other hand, it will not be necessary for future
unemployment to rise back to the level thought to be the NAIRU in the mid-1990s. The apparent NAIRU has fallen in 1996-1999 relative to 1962-1995 both because g-A has been positive in the later period and because it was negative on average in the earlier period. The average g-A over 1962-1995 is negative because, as shown in Figures 1-3, A lagged behind the falling g during the productivity slowdown. In steady state, the economy must give up the gains from today's positive g-A's, but not the gains from eliminating negative g-A's. In other words, the true NAIRU is higher than the apparent NAIRU of today, but lower than the apparent NAIRU before 1996, when unemployment was raised by slow adjustment of aspirations to the productivity slowdown.

Specifically, recall that estimating the Phillips curve for 1962-1995 without the g-A term yields a NAIRU estimate of 6.2%. In contrast, the equation with g-A implies a NAIRU of 5.2% (for $\beta=0.95$). 5.2% is our estimate of the unemployment rate consistent with stable inflation when g-A equals zero. Thus, if the true Phillips curve has not shifted since 1995, our equation implies that unemployment must eventually rise to 5.2% from its 1999 level of 4.2%. However, it need not rise all the way to the 6.2% level suggested by a conventional Phillips curve.
VI. EXTENSIONS

This section considers various extensions of our time-series analysis.

A. The Wage Phillips Curve

So far we have focused on our model's implications for price inflation. To further test the model, we now turn to the wage Phillips curve, equation (3). Recall that wage inflation depends on lagged price inflation, unemployment, and a weighted average of g and A. We also consider the neoclassical special case in which the weight on g is constrained to be one.

Table 2 presents estimates of wage Phillips curves for 1962-1995 ($\beta=0.95$). These estimates support the model. The estimated weights on g and A are 0.23 and 0.77; these are not significantly different from the 0.39 and 0.61 implied by the price Phillips curve. The hypothesis that the weight on g is one is strongly rejected, and the hypothesis that this weight is zero is not rejected ($t=1.2$). When we relax the restriction that the g and A coefficients sum to one, it is not rejected ($t=0.3$).

Using the estimates for 1962-1995, Table 2 also reports forecast errors for $\pi^w-\pi_{-1}$ after 1995. The results parallel
those for price Phillips curves. The neoclassical equation overpredicts wage inflation relative to $\pi_1$ by a total of 3.9 percentage points. This equation predicts that wage growth rises one-for-one with the productivity acceleration, when in fact the immediate effect was much smaller. In contrast, our wage Phillips curve is accurate: it underpredicts wage growth by an insignificant amount.

**B. Additional Phillips-Curve Variables**

Most authors who estimate Phillips curves include additional variables, in particular lags of unemployment and inflation changes and measures of supply shocks (e.g. Gordon, 1998; Staiger et al., 1997). Here we check the robustness of our conclusions to adding such variables. In the results reported here, we experiment with two lags of the change in inflation; unemployment lags are never significant, so we omit results with these variables. To measure supply shocks, we use three standard variables: the change in the relative price of food and energy, the change in the trade-weighted real exchange rate, and Gordon's dummy for the Nixon price controls.5

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5 The change in the relative price of food and energy is the difference between the log change in the food-energy component of the CPI and the log change in the CPI. The trade-weighted real exchange rate is from Data Resources, Inc. The Nixon dummy equals 0.5 in 1972 and 1973, -0.3 in 1974, and -0.7 in 1975.
Table 3 presents estimates of our generalized Phillips curves for 1962-1995. We estimate equations with and without the three supply shocks, with and without the two \( \Delta \pi \) lags, and with and without \( g-A \), in all possible combinations. In all cases, we set \( \beta=0.95 \) in calculating \( A \). There are two robust conclusions. First, the three supply shocks are jointly significant and so are the two \( \Delta \pi \) lags, regardless of whether \( g-A \) is included. The various coefficients have reasonable signs and magnitudes. Including all the variables (column (8)) yields an \( R^2 \) of 0.81.

Second, the term \( g-A \) remains significant in all the specifications. However, the magnitude of the coefficient generally falls when additional variables are added. In the most general specification, the coefficient is \(-0.29\) (t=2.6), compared to \(-0.61\) when the supply shocks and \( \Delta \pi \) lags are excluded.6

Figure 6 shows forecasts of inflation for 1996-1999 based on the 1962-1995 estimates. The four panels give results with and without the supply shocks and with and without inflation

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6 The proper interpretation of the lower coefficient is not clear. According to our model, it implies a lower coefficient on \( A \) in the target-wage equation and a higher coefficient on \( g \). However, estimating these coefficients from wage- rather than price-Phillips curves yields a coefficient on \( A \) near 0.7 regardless of whether supply shocks and inflation lags are included in the equation.
lags. In each case, we show actual inflation and the forecasts for inflation that arise when g-A is included and when it is excluded. The forecasts vary across specifications, but robust conclusions again emerge. First, if one leaves g-A out of the Phillips curve, adding the supply shocks helps reduce the overprediction of inflation over the recent period. In the most general specification without g-A, predicted inflation in 1999 is 4.4%, compared to 6.9% for a Phillips curve that includes only unemployment. These results reflect the fall in energy prices in 1998 and the dollar appreciation over 1996-1998, which help to hold down predicted inflation.

Second, including g-A still reduces the overprediction of inflation (or, in one case, turns moderate overprediction into moderate underprediction). In the specification with both supply shocks and $\Delta \pi$ lags, the forecast for inflation in 1999 is 4.4% when g-A is excluded and 2.6% when it is included; the latter is close to the actual value of 2.2%.

Figure 7 shows another way of disentangling the roles of g-A and supply shocks. The table reproduces actual inflation and forecasts of inflation from our most general equation, (8). It adds forecasts implied by various counterfactual
assumptions about the post-1995 economy. In one
counterfactual, the three supply shocks are set at their
average values over 1962-1995, in another g-A is set at its
average value, and in the third both g-A and supply shocks are
set at average values. Comparing our forecasts based on the
actual data to those based on the counterfactuals, we find
that inflation in 1999 would have been 1.9 points higher if
there had been no productivity acceleration, 1.5 points higher
if there were no supply shocks, and 3.4 points higher if
neither occurred. (We expect that the importance of g-A
relative to supply shocks will increase when we extend the
forecasts through 2000.)

C. Time-Varying NAIRUs

The recent behavior of unemployment and inflation has
suggested to many observers that the NAIRU has fallen. This
has led to increased interest in estimating Phillips curves
with time-varying NAIRUs (e.g. Staiger et al. and Gordon). So
far this paper has estimated constant-NAIRU models. However,
our idea that a such a model forecasts inflation better when
g-A is included can be turned around to say that there appears
to be less time-variation in the NAIRU once g-A is included.
In particular, the NAIRU falls less since 1995 if we account
for the anti-inflationary role of the productivity
acceleration. Here we explore this version of our story.

As a first pass, we estimate time-varying NAIRUs in the following way. We start with the simple Phillips curves we have already estimated. Shocks to these equations, captured by the error terms, cause fluctuations in the level of unemployment consistent with stable inflation. For example, in 1974 it would have taken very high unemployment to offset the effects of the OPEC shock and keep inflation stable. As discussed earlier, economists generally do not interpret these shocks as year-to-year fluctuations in the NAIRU. Instead, they assume that the NAIRU changes gradually, and interpret shifts in the U/π relation as NAIRU shifts only if they appear persistent. In this spirit, we define the time-varying NAIRU as the long-term component of movements in the U/π relation.

Specifically, consider two simple Phillips curves:

\begin{align}
\Delta \pi &= -\gamma (U - U^*) ; \\
\Delta \pi &= -\gamma (U - U^*) + (1 - \delta) (g - A) .
\end{align}

If U* is a constant, these reduce to the Phillips curves with and without g-A that we estimate above. We impose the values of γ and (1−δ) that we obtain by estimating constant-U* equations over 1962-1999: γ=0.633 in (6a) and γ=0.646, (1−δ)=0.594 in (6b). Given these coefficients and the data on
\(\Delta \pi, U, \text{ and } g-A\), each equation defines a series for \(U^*\) over 1962-1999. In (6a), \(U^*\) is the unemployment rate that would produce stable inflation; in (6b) it is the unemployment rate that would produce stable inflation if \(g-A=0\). Finally, we extract a long-term trend from each \(U^*\) series using the Hodrick-Prescott filter with parameter 100. These smoothed series are our measures of time-varying NAIRUs.

Figure 8 presents the \(U^*\) and smoothed-\(U^*\) series for each equation. Note first that the average \(U^*\) is 6.1\% when \(g-A\) is excluded from the Phillips curve and 5.2\% when it is included.

This result confirms our earlier finding that the inclusion of \(g-A\) reduces the NAIRU when it is assumed to be fixed. The new result is that adding \(g-A\) also reduces the time-variation in the NAIRU. When \(g-A\) is excluded, the smoothed \(U^*\) rises by 2.0 percentage points from 1962 to 1978, then falls by 2.8 points from 1978 to 1999. This hump-shaped path is broadly similar to the NAIRU behavior estimated by previous authors. When \(g-A\) is included, the qualitative pattern is similar but the movements are smaller: the NAIRU rises only 0.5 points from 1962 to 1978 (although it dips along the way), and it falls only 0.9 points from 1978 to 1999. The NAIRU fall from 1990 to 1999 -- a rough measure of the New-Economy effect -- is 1.7 points without \(g-A\) and 0.4 points with \(g-A\). Once \(g-A\)
is included, there is little need to search for explanations for a falling NAIRU.

The choice of a smoothing parameter for the HP filter is arbitrary. Increasing the parameter reduces the time-variation in both NAIRU series, but does not change the result that the NAIRU is more stable when g-A is included.

VII. THE CHILEAN MIRACLE

So far we have focused on the United States. It is natural to ask whether our theory also helps explain apparent Phillips-curve shifts in other countries. The experience of the 1970s suggests that it does. Productivity growth slowed throughout the OECD during the 70s, and this was accompanied by an apparent rise in the NAIRU in most countries. Grubb et al. (1982) and many subsequent authors discuss this experience.

Unfortunately, it is difficult to produce international evidence for our theory beyond a broad observation about the 1970s. One might hope to find a cross-country relation between the size of productivity slowdowns or speedups and the size of apparent NAIRU shifts. Our look at the data suggests, however, that no clear relation exists. The problem is that the NAIRU has moved sharply in various countries for reasons
unrelated to our model, such as labor-market institutions and the long-run effects of monetary policy (see Blanchard and Wolfers, 1999, and Ball, 1999). These NAIRU movements swamp the effects of productivity shifts that we would like to detect. The U.S. data provide more evidence about our theory because there have not been other factors causing large shifts in the NAIRU.

The good news is that examining the cross-country data yields one useful case study: the experience of Chile in the 1990s. Chile had a major productivity acceleration during this period, an experience usually attributed to economic liberalization. Figure 9 plots the growth rate of labor productivity in Chile for 1976-1997 (measured as growth in output per worker, from World Development Indicators). Average productivity growth was 0.85 percent over the ten years from 1977 to 1987 and 4.96 percent over 1987-1997. The increase of 4.11 percent is much larger than the recent productivity acceleration in the United States.

Indeed, the Chilean episode is an outlier in international data. There are 40 countries for which 20 or more years of data on productivity growth are available from either the WDI or the OECD. (The starting dates range from 1961 to 1977 and the ending dates from 1992 to 2000.) For
each of these countries, we computed the largest productivity acceleration, defined as the largest difference between average productivity growth in one ten year period and the previous ten year period. For Chile, the largest is the 4.11 percent increase between 1977-1987 and 1987-1997. This is the largest acceleration for any country in the sample. The country with the next largest acceleration is Jamaica, with 3.27%, but this resulted from an increase from -4.39 percent to -1.12 percent. After that comes Thailand, with an acceleration of 2.96 percent from 1976-86 to 1986-96. Only three other countries have accelerations greater than 2% starting from a positive initial growth rate. Thus Chile's productivity acceleration is more than twice as large as the largest one experienced by most countries, and it is more than a full point above the second-largest in the sample (ignoring Jamaica).

If productivity shifts affect the Phillips curve, there should have been a favorable Phillips-curve shift in Chile. And there was. The shift took a different form than the recent shift in the U.S.: it showed up mainly as falling inflation with stable unemployment rather than vice-versa. That is, Chile had the rare experience of a costless disinflation. Research has shown that a substantial fall in
inflation is almost always accompanied by output losses and a rise in unemployment. For example, Ball (1994) examines 28 disinflations in OECD countries between 1960 and 1991 and finds adverse output effects in 27 of them. Dornbusch and Fischer (1993) present evidence that disinflations from moderate levels cause output losses in middle-income countries as well.

Chile is a stark exception to this stylized fact. Figure 10 plots inflation, unemployment, and output growth from 1985 through 1997 (after which the miracle was interrupted by the world financial crisis). As shown in the Figure, inflation peaked at 26% in 1990 and then fell steadily, reaching 3% in 1997. But one can detect no adverse effects on the real economy. Unemployment was 9.6% in 1990 and fell to 6.6% in 1997. Output growth was consistently high over the period: its two lowest levels were 3.7% in 1990 and 5.7% in 1994.7

Thus the Chilean episode combined a highly unusual productivity acceleration with a highly unusual shift in the Phillips curve. It stands out from the cross-country data on both counts. Of course the Phillips curve might have shifted for some other reason, but we doubt it. A leading view within Chile is that inflation expectations shifted because the

7 The data on inflation and output growth are from the Bank of Chile. The
central bank introduced a credible policy of inflation targeting (e.g. Corbo, 1998). However, other countries have adopted inflation targeting, and research has not detected a favorable effect on the Phillips curve. Disinflations usually cause recessions even under inflation targeting (Bernanke et al., 2001).

VIII. MICRO EVIDENCE

The evidence presented thus far has been based on aggregate relationships between price and wage inflation, the unemployment rate, and lagged real-wage growth. It is useful to disaggregate the analysis by skill groups in the labor market to determine whether these results apply to all skill groups or only some. We examine how our wage-aspiration variable A has behaved for different skill groups and whether it has the expected positive effect in the wage Phillips curve for all those groups.

Following Katz and Krueger (1999), we use individual data from the Current Population Survey (CPS). The May CPS is available from 1973-1978 and Outgoing Rotation Group data are available from 1979-1999. We take both hourly wage and weekly wage measures from the data, for the latter are more reliably

data on unemployment (in Santiago) are from the University of Chile.
measured. Like Katz and Krueger, we measure skill by education level and consider four education groups: less than high school, high school, some college, and college degree or more. Because we are interested in lagged wages, we divide the data not only by year and education but also by birth year (i.e., cohort) so as to be able to construct wage profiles for a cohort over its lifetime. All workers aged 25-64 are used to form the year-education-cohort cells, of which there are 888 over the period of the data. Within each cell we compute not only mean log real wage growth but also median log real wage growth, for medians are less sensitive to outliers.

The equation we estimate is a micro version of the aggregate wage Phillips curve presented earlier:

\[
\pi^w(e,c,t) - \pi(t-1) = a(e) + b(t) - \gamma U(e,t) + (1 - \delta) A(e,c,t),
\]

where \( \pi^w(e,c,t) \) is the growth rate of the log hourly wage for education group \( e \) and cohort \( c \) in year \( t \); \( \pi(t-1) \) is price inflation at \( t-1 \); \( U(e,t) \) are BLS-published unemployment rates by education group in each year; and \( A(e,c,t) \) is an average of past wages for education group \( e \) and cohort \( c \) in year \( t \). \( A \) is constructed exactly as described elsewhere in this paper, using a \( \beta \) of .95 and an HP-filtered value for the start of the process in 1974 -- but using each cohort's own lagged-wage
profiles by age and year.

The major difference between equation (7) and the aggregate equations estimated earlier is the absence of a productivity variable. Unfortunately, productivity data are unavailable for education groups and other disaggregate portions of the labor force, and hence it must be omitted. Instead, a full set of education and year dummies are included \( (a(e) \text{ and } b(t)) \). These dummies capture all productivity growth that is common to all groups in each year (i.e., aggregate) as well as all productivity growth that is common to each education group in all years. It omits that portion of productivity growth that is specific to different education groups in different years. However, productivity shocks of that variety should be orthogonal to lagged wages and hence to \( A \), and thus should not bias the coefficients.

The practical consequence of including education and year dummies is that the coefficients \( \gamma \) and \( 1-\delta \) will entirely reflect cross-sectional relationships between the unemployment rate and \( A \) for different education groups, on the one hand, and the subsequent real wage growth for those groups, on the other, net of an overall trend for each education group.

Table 4 shows the results of the estimation. The results are fairly insensitive to whether mean or median growth is
examined, and whether hourly or weekly wage growth is the object of estimation. The expected negative effect of the unemployment rate is found -- less educated groups have the highest unemployment rates and also the lowest real wage growth -- and, most important, a cohort's wage aspiration as measured by its own wage history is positively related to its subsequent real wage growth. The magnitudes of the A coefficients range from 0.61 to 0.74, in the same range as those estimated from aggregate data. These cross-sectional results thus are strongly consistent with the time series results presented previously.

Tests for whether the coefficients on the unemployment rate and A are different for the four different education groups reveal, perhaps surprisingly, no significant differences. However, most past work on the cyclicality of the workforce by skill group has measured cyclicality relative to the aggregate unemployment rate, not the skill-specific unemployment rate used here. Also, while A can be different across skill groups, there is no reason to expect that the response to lagged wages will be different by skill.

Further inspection of the results reveals that A has been drifting upward for the more educated groups and downward for the less educated groups, thus providing very different
patterns of wage growth. Note that $A$ represents real-wage growth in the past, not the level of the wage, so this is not necessarily to be expected from the well-known increasing dispersion of wages by education level. Instead, it implies that the spreading out accelerated over much of the period we are examining. On net, because the values of $A$ for the less educated group have declined so severely, the average $A$ has also fallen, consistent with the aggregate data. However, the less-educated groups experienced above-average real-wage growth in the second half of the 1990s, and so the declines in $A$ for those groups slowed significantly.

IX. CONCLUSION

This paper proposes a new variable for the Phillips curve: the difference between productivity growth and an average of past real-wage growth. Theoretically, this variable appears if workers' aspirations for real-wage increases adjust slowly to shifts in productivity growth. Empirically, our new variable shows up strongly in the U.S. Phillips curve. Including it explains most of the otherwise-puzzling shift in the inflation-unemployment relation since 1995.

Our theory contributes to a parsimonious interpretation
of macroeconomic history. It yields a unified explanation of why unemployment rose during the productivity slowdown of the 1970s and why it has fallen since 1995. The theory also explains part of the year-to-year fluctuations in the unemployment-inflation tradeoff as arising from fluctuations in productivity growth. Finally, our story links two features of the post-1995 New Economy. The Phillips curve shift was caused by the productivity acceleration rather than happening to occur at the same time for some other reason.

In the mid-1990s, the consensus estimate of the NAIRU was 6%. Since then, unemployment has fallen near 4%, and inflation has not risen substantially. Our results suggest that the non-inflationary fall in unemployment is partly but not entirely sustainable. The economy has moved from a regime in which wage aspirations exceeded productivity growth, raising unemployment, to one in which aspirations are below productivity growth. Eventually the economy must move toward a steady state in between. We estimate the NAIRU in this steady state to be around 5.2%. 

40
REFERENCES


Blanchard, Olivier and Lawrence F. Katz, “What We Know and Do Not Know About the Natural Rate of Unemployment,” Journal of Economic Perspectives 11 (Winter, 1997), 51-72.


(Dependent Variable: Δπ)

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(Dependent Variable: $\pi^W - \pi_{-1}$)

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(Dependent Variable: $\Delta \pi$)

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Table 4

Wage Phillips Curve Estimated on Micro Data

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Notes: N=888. Standard errors in parentheses.
Figure 1. Cyclically-Adjusted Productivity Growth (g).
Figure 2. Real-Wage Growth and Aspirations.

Actual Real-Wage Growth

A(\(\beta = 1.0\))

A(\(\beta = 0.95\))

A(\(\beta = 0.9\))

A(\(\beta = 0.5\))

A(\(\beta = 0.75\))
Figure 3. The Gap Between Productivity Growth and Aspirations ($\beta=0.95$).
Figure 4. Dynamic Inflation Forecasts: Conventional Phillips Curve.
Figure 5. Dynamic Inflation Forecasts: Phillips Curve with g-A.
Figure 6. Dynamic Inflation Forecasts: Generalized Phillips Curves.

Simple Phillips Curves

Phillips Curves with $\Delta \pi$ Lags

Phillips Curves with Supply Shocks

Phillips Curves with Supply Shocks and $\Delta \pi$ Lags
Figure 7. Dynamic Inflation Forecasts Under Counterfactual Assumptions.

- Forecast if g-A and supply shocks = pre-1996 averages
- Forecast if g-A = pre-1996 average
- Forecast if supply shocks = pre-1996 averages
- Forecast based on actual data
- Actual Inflation
Figure 8. A Time-Varying NAIRU?

Phillips Curve without g-A

Phillips Curve with g-A
Figure 9. Productivity Growth in Chile.
Figure 10. Chile’s Phillips-Curve Shift.

Inflation

Unemployment (Santiago)

Output Growth